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ORIGINAL ARTICLES.

I.—Note on the Silurian Inlier near Cardiff.

By F. J. North, B.Sc., F.G.S., Assistant Keeper, Geological Department, National Museum of Wales.

(PLATE XIII.)

TO the north and north-east of Cardiff there is a small inlier of Silurian rocks (described in detail by Professor Sollas in 1879[1]) covering an area of rather more than two square miles. There are representatives of both the Ludlow and the Wenlock Series, and the general dip of the beds is towards the north, in which direction Ludlow mudstones pass with apparent conformity beneath the Old Red Sandstone.

That there was a considerable underground extension of strata older than the Old Red Sandstone was inferred from the fact that grey mudstones containing fossils ("brachiopods and encrinites"), and regarded as of Silurian age, had been recorded immediately beneath the Trias in deep borings in the vicinity, viz. Crown Fuel Works, Roath Dock[2]; Crawshay Street[3]; and the Ely Paper Mills[4]; but there was no definite evidence as to the structure and extent of the concealed rocks. (The sites of these borings are indicated on the accompanying Map, Plate XIII, by A, B, and C respectively.)

The dip of the Wenlock Beds in the southernmost exposures at Pen-y-lan is toward the south,[5] but this does not necessarily imply that a southerly dip would prevail, since minor folds have been noticed further north. In the Survey Memoir[6] we read: "... it by no means follows that the main axis of the Silurian inlier has been passed; [*at Pen-y-lan*] rocks older than any exposed at the surface may crop out under the New Red Marls at Roath."

Important evidence bearing upon this question has recently been afforded by a deep boring for water, full details of which will be published later. The boring, which was discontinued in December, 1914, after having reached a depth of 627 feet without encountering water, was made on the site of the new premises of Messrs. S. A. Brain & Co., who generously placed the cores at the disposal of the National Museum of Wales.

[1] J. W. Sollas, Q.J.G.S., vol. xxxv, pp. 475–507, 1879.
[2] *The Country around Cardiff* (Mem. Geol. Surv.), 1912, p. 99.
[3] Ibid., p. 100.
[4] Ibid., p. 99.
[5] J. W. Sollas, Q.J.G.S., vol. xxxv, p. 477, 1879.
[6] *The Country around Cardiff* (Mem. Geol. Surv.), 1912, p. 5.

SECTION OF THE BOREHOLE.

Site of boring, the southern end of Helen Street,[1] *Roath; 6 in. ordnance map, Glam. 43, S.E. Height of surface above O.D. 38 feet.*

	Thickness. ft.	in.	Depth from surface. ft.	in.
Superficial deposits.				
Soil and terrace gravels	23	0	23	0
Trias.				
Red and green Keuper marls with gypsum .	265	3	288	3
Conglomeratic series	53	9	342	0
Old Red Sandstone.				
Purple micaceous sandstone, mottled marls with cornstones; grit band at the base .	132	0	474	0
Silurian (Ludlow).				
Red and grey fossiliferous mudstones, with sandstones and very thin calcareous bands.	152	7	626	7

The lower part of the Old Red Sandstone Series includes red micaceous mudstones in which *Lingula* and crustacean tracks occur. Beneath the mudstones there are about 6 feet of a hard grit containing fragments of the underlying rock. Mr. T. C. Cantrill, who has kindly examined some of the specimens, compares the crustacean tracks to those described by G. E. Roberts from the lower part of the Old Red Sandstone at Bouldon Quarry, near Ludlow.[2]

The Silurian rocks yielded a rich fauna, including many Mollusca, Brachiopoda, and Trilobita. The beds are regarded as of Ludlow age, for although many of the forms present are such as occur in both Wenlock and Ludlow beds of other localities, certain species, e.g., *Homalonotus knightii*, König, *Murchisonia lloydi*, J. de C. Sowerby, *Stropheodonta filosa* (J. de C. Sowerby), *Chonetes striatella* (Dalman), and *Cyclonema turbinatum*, Sollas, are especially characteristic of the local Ludlow beds.

The general direction of the concealed boundary between the Silurian and the Old Red Sandstone can now be inferred from the following evidence:—

1. Trias was found to rest upon Silurian strata in a boring by the side of the Rhymney Railway, about 500 yards south of the main Silurian outcrop,[3] at a spot indicated by E on the accompanying map.

2. In the Cardiff Brick Company's pit at Maendy (F on the map), Trias rests upon Old Red Sandstone.[4]

3. In the Helen Street boring, now described, Trias rests upon Old Red Sandstone.

The junction therefore occurs north of a line from Maendy to Helen Street, and south of the spot E; its approximate position is indicated on the map.

If the Trias were removed, the Cardiff Silurian inlier would appear as an oval mass, about three miles from east to west and about two miles from north to south. Structurally it is an anticlinal fold, trending in an east to west direction, i.e. in the direction of the

[1] Indicated by D on the accompanying Map (Plate XIII).
[2] G. E. Roberts, Q.J.G.S., vol. xix, pp. 233–5, 1863.
[3] *The Country around Cardiff* (Mem. Geol. Surv.), 1912, p. 105.
[4] Ibid., p. 17.

greater Cardiff–Cowbridge anticline. The occurrence of Silurian rocks beneath the surface at the localities already cited does not indicate one continuous Silurian mass, immediately beneath the Trias, extending from Pen-y-lan on the north to the Bristol Channel on the south, and from Rumney on the east at least as far as Ely on the west. There are probably several small oval areas which owe their existence to pre-Triassic folding and denudation. In conclusion, the writer would express his thanks to Professor T. Franklin Sibly for his advice while the work was in progress.

II.—The Genera of Recent and Tertiary Rhynchonellids.

By J. Allan Thomson, M.A., D.Sc., F.G.S.

OWING to the marked persistence of general external form and internal characters in the Rhynchonellidæ, it is necessary in this family to seize on slighter differences for the foundation of genera than is elsewhere necessary or advisable.[1] The object of this paper is to point out the characters that have been used and others which may advantageously be introduced in the discrimination of the genera of Recent and Tertiary representatives of the group. These are not at present distributed by authors amongst the genera *Rhynchonella*, Fischer; *Acanthothyris*, d'Orbigny; *Hemithyris*, d'Orbigny; *Cryptopora*, Jeffreys (syn. *Atretia*, *Neatretia*); *Frieleia*, Dall; and *Basiola*, Dall.

Surface Ornament.

Buckman in a recent paper[2] divides Jurassic Rhynchonellids into three main series—*Læves*, *Capillatæ*, *Ornatæ*. "*Læves* are smooth and develop ribs directly on a smooth stage; *Capillatæ* have hair-like lines (*striæ*) and then may develop ribs; and *Ornatæ* have additional ornament like imbrication, or spines."[3] In making this statement Buckman cannot be taken to mean that the three series obtained by a consideration of surface ornament are natural groups, equivalent for instance to sub-families, since he has already recognized smooth, ribbed, imbricate, and spinous species in a single genus, *Hemithyris*. Schuchert[4] and others have placed the Recent Japanese spinous species, *Rhynchonella döderleini*, Davidson, under *Acanthothyris* solely on account of the possession of spines, and Buckman has strongly criticized this course. "Spinosity is in itself not a generic character, it is only a stage of development to which various stocks attain. *R. döderleini* can have no connexion with the Jurassic species of *Acanthothyris*; and

[1] Cf. J. Hall and J. M. Clarke, "An Introduction to the Study of the Brachiopoda, etc.": 47th Ann. Rep. New York State Museum, 1894, pp. 1016–17.

[2] S. S. Buckman, "The Brachiopoda of the Namyau Beds of Burmah: Preliminary Notice": Rec. Geol. Surv. India, vol. xlv, pt. i, pp. 75–81, 1915.

[3] "The type of *Rhynchonella*, *R. loxia*, Fischer, is one of the *Capillatæ*. The *acuta* group, which so resembles it, belongs to the *Læves*, and so must be removed. The result is that *Rhynchonella*, which once covered hundreds of species from Ordovician to Recent, must now be confined, so far as present knowledge goes, to one species, *R. loxia*" (Buckman, loc. cit.).

[4] C. Schuchert, Brachiopoda in Zittel, *Textbook of Palæontology*, translated by C. R. Eastman, 2nd ed., 1913, p. 400.

it is more probably a spinous development of *Hemithyris nigricans*."[1] Chapman[2] also speaks of *Acanthothyris squamosa* (Hutton), and here the same argument applies; this species, which is imbricate in ornament, presents all the characters of *Hemithyris*, to which genus it should be assigned. It is probable that *Hemithyris nigricans*, which is coarsely ribbed and not imbricate, is a catagenetic development of a coarsely ribbed, imbricate, Oamaruian (probably Miocene) species, not yet named, which differs from *H. squamosa* in its much coarser ribs, while *H. döderleini* may be a spinous (anagenetic) development of the same imbricate ancestor.

If spinosity is not in itself a generic character, it is still less of sub-family value. Schuchert has used it to separate *Acanthothyris* under the Acanthothyrinæ from the majority of smooth or ribbed Mesozoic and later Rhynchonellids which are placed in the Rhynchonellinæ. Without doubt *Acanthothyris* is a spinous development of one of the Jurassic ribbed stocks distinguished by Buckman, and some other characters must be employed if the Rhynchonellidæ are to be subdivided into natural sub-families.

Types of Folding.[3]

Of the characters liable to variation in the family, one to which few exceptions exist is the more or less strong dorsal uniplication, which finds its greatest expression in *Rhynchonella* itself. In *Hemithyris* this type of folding is present but not always strongly marked, some of the species being almost non-plicate, but the southern fossil forms of the *H. nigricans* series are often strongly folded. Biplication is not known amongst Rhynchonellids, with the exception of *Rhynchonella salpinx*, Dall,[4] an American Eocene form which is narrowly biplicate with two additional lateral folds. This species has not only the type of folding characteristic of *Dallina*, but has also Dalliniform beak characters, and as the internal characters are unknown it is more than likely that it is not a Rhynchonellid, but a Terebratulid in which the pores have been filled up by an unusual process of fossilization.

Ventral uniplication is well marked in the Triassic *Norella*, Bittner, and is incipiently displayed by the Recent *Cryptopora*, Jeffreys. Dall has described under the name of *Hemithyris strebeli*[5] a mid-Pacific abyssal shell which shows clear ventral uniplication, and therefore cannot belong to *Hemithyris*, but must be placed in a new genus.

Neorhynchia, gen. nov.

Genotype *Hemithyris strebeli*, Dall.

Ventrally uniplicate, shell thin, broad, smooth. Beak hypothyrid. Dorsal valve with a thin, thread-like septum, no hinge-plate. Ventral

[1] S. S. Buckman, "Antarctic Fossil Brachiopoda collected by the Swedish South Polar Expedition": Wissensch. Ergeb. Schwed. Südpolar-Exped., 1901–3, Bd. iii, Lief. vii, p. 11, 1910.

[2] F. Chapman, *Australasian Fossils*, Melbourne, 1914, p. 167.

[3] Cf. J. A. Thomson, "Brachiopod Morphology: Types of Folding in the Terebratulacea": Geol. Mag., Dec. VI, Vol. II, pp. 71–6, 1915.

[4] Trans. Wagner. Free Inst. Sci. Philadelphia, vol. iii, pt. vi, pp. 1535–6, pl. lviii, figs. 5–7, 1903.

[5] Bull. Mus. Comp. Zool. Harvard, vol. xliii, p. 441, 1908.

valve without septum, hinge-teeth supported by dental plates. Muscular impressions obscure.

Folding of the *Cincta* type is rare amongst Rhynchonellids, but is exhibited by the Triassic *Halorella*, Bittner. *Frieleia*, Dall, is practically non-plicate, but it seems from Dall's description that there is a faint sinus in each valve.

Characters of Beak and Delthyrium.

Buckman[1] has introduced the terms 'hypothyrid' and 'epithyrid' to designate two contrasted types of beak characters, a shell being hypothyrid when it exhibits a distinct oval or circular opening below the apex, and epithyrid when it exhibits a truncate perforate beak. The possession of hypothyrid beak characters is an almost constant characteristic of Rhynchonellids, but *Terebratuloidea*, Waagen, and *Peregrinella*, Oehlert, are epithyrid with large foramens. There is a Tertiary series of Rhynchonellids, mostly smooth, which exhibits epithyrid beak characters with minute foramen, and these require generic recognition.

Ætheia, gen. nov.

Genotype *Waldheimia* (?) *sinuata*, Hutton[2] = *Terebratula gaulteri*, Morris.[3]

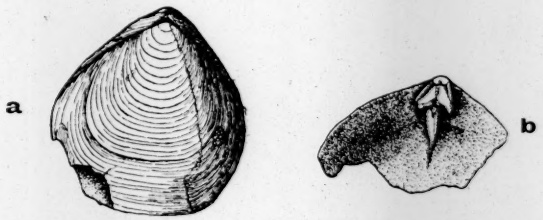

Fig. 1.—*Ætheia gaulteri* (Morris), Oamaruian, New Zealand: a, holotype of *Waldheimia sinuata*, Hutton, Curiosity Shop, Canterbury; b, interior of posterior part of dorsal valve, showing septum and cardinalia (crura broken), Squire's, South Canterbury.

Dorsally uniplicate. Beak epithyrid, with a minute foramen. Dorsal valve with high socket ridges, and a short stout low septum, rising rapidly posteriorly, fusing with the crural bases and supporting a short cardinal process. Hinge-teeth of ventral valve transversely striated, not supported by dental plates. Muscular impressions small but well marked, posterior, close. The genotype is perfectly smooth.

Buckman has described a smooth Rhynchonellid from the Antarctic Miocene under the name of *Hemithyris australis*, and states that it belongs to the *Rhynchonella bipartita* series, in which he apparently places also *R. bolcensis* (Massalongo) and *R. lucida*, Gould. *R. bipartita*

[1] Ann. Mag. Nat. Hist., ser. vii, vol. xviii, pp. 322–3, 1906.

[2] Cat. Tert. Moll. Ech. New Zealand, 1873, p. 36.

[3] Quart. Journ. Geol. Soc., vol. vi, p. 329, pl. xxviii, figs. 2, 3, 1850. The type of this species is lost, and some doubt may attach to the identification of *W. sinuata*, Hutton, with it. As the internal characters of the genus have been worked out on specimens agreeing with the type of the latter species, it is chosen for the genotype.

(Brocchi) occurs in the Miocene of Malta and Italy, *R. bolcensis* in the Eocene of Italy, and *R. lucida* in the Recent seas of Japan. Whether any of these species belong to *Ætheia* cannot be decided until their internal characters have been examined, and the same applies to the smooth Cretaceous Rhynchonellids such as *R. limbata* (Schlotheim). It may be pointed out, however, that according to Davidson's descriptions [1] the foramens of *R. bipartita* and *R. lucida* are not apical but lie beneath the beak, so that it is quite probable that these species are correctly referred to *Hemithyris*, while on the other hand those of *R. limbata* and of *R. bolcensis* are minute, as in *Ætheia*, and apical so far as the figures can be trusted.

Rhynchonella patagonica, Ihering,[2] from the Patagonian formation, appears to belong to *Ætheia*, for according to Ihering it possesses the minute apical foramen, while the internal characters, so far as can be judged from the figures, agree well with those of the genotype. Ihering had already noticed the peculiarities of the beak, and remarked that he believed that the species should be placed in a different sub-genus. *Ætheia patagonica* is of interest in possessing numerous very fine squamosal ribs, showing that in this, as in other stocks, the ornament cannot be considered a character of generic value.

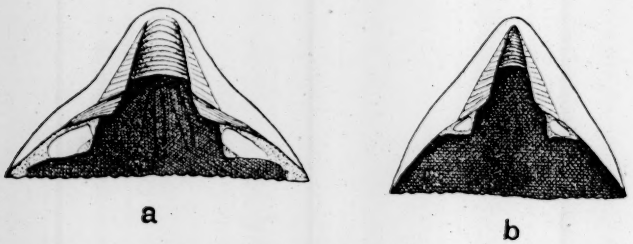

FIG. 2.—Beak of *Hemithyris*, enlarged dorsal view, showing deltidial plates. a, *H. nigricans*; b, *H. psittacea*.

The manner in which the delthyrium of *Hemithyris* becomes partially closed is not well understood. In most recent species, including the genotype, *H. psittacea*, there is a large pedicle opening in front of the beak, margined laterally by two deltidial plates, and in front by the umbo of the dorsal valve. In some Tertiary species the lateral deltidial plates unite at their bases and thus separate a hypothyrid foramen from the dorsal valve, and this is the case also in *Basiola*, Dall.[3] In all cases, however, the deltidial plates are not confined to the dorsal part of the delthyrium, but are reflected down the sides and unite ventrally in a plate which is joined behind to the inner side of the apex, but is free in front and separated from the shell by a narrow cavity (Fig. 2). The pedicle, therefore, is surrounded on three sides by deltidial plates in species of *Hemithyris*

[1] Ann. Mag. Nat. Hist., ser. III, vol. xiv, p. 10, 1864; GEOL. MAG., Dec. I, Vol. VII, pp. 460–1, 1870; Mon. Brit. Foss. Brach., pt. ii, pp. 79–80, 1855; Trans. Linn. Soc. Lond., vol. iv, pt. ii, pp. 168–9, 1887.

[2] Ann. Mus. Nac. Buenos Aires, t. ix, pp. 334–5, figs. 11, *a–b*, 1903.

[3] Bull. Mus. Comp. Zool. Harvard, vol. xliii, p. 442, 1908.

with discrete deltidial plates, and is completely enclosed in a funnel-shaped pseudo-deltidium in those species where the upper deltidial plates unite, including *Basiola beecheri* (Dall). *Basiola* is merely a *Hemithyris* in which the dorsal deltidial plates are united, a difference hardly entitling it to separate generic rank.

Hinge-teeth and Dental Plates.

The majority of Rhynchonellids have hinge-teeth in the ventral valve supported by dental plates. This is the case in all the Tertiary and Recent genera here noticed with the exception of *Ætheia*. In *Hemithyris* the dental plates are slender but quite distinct, and are clearly mentioned in the descriptions of species by Davidson, Dall, and others. Nevertheless the statement is made by Hall & Clarke [1] that dental plates are absent in this genus, and this error has been copied by Schuchert,[2] and has led Buckman [3] to state that *Hemithyris imbricata* is correctly placed under *Hemithyris* on account of the apparent absence of dental plates amongst other characters.[4]

Cardinalia and Septa of Dorsal Valve.

Cardinalia is a new term to embrace collectively the socket walls or ridges, crural bases, hinge-plate, and cardinal process of the dorsal valve. These parts are in some genera so intimately united that they cannot be separately described, e.g. in *Bouchardia*. When a septum is present in the dorsal valve it often unites posteriorly with the cardinalia. The socket-ridges are the processes forming the inner walls of the dental sockets and bearing on their inner sides the crural bases, hinge-plate, etc. They are by some authors confused with the cardinal process, while Dall consistently speaks of them as the hinge-teeth of the dorsal valve but as they do not fit into corresponding sockets in the ventral valve, the other term of King is preferable.[5] A cardinal process, either resting directly on the apex of the valve, or resting on an excavate hinge-plate supported by a septum, or resting directly on the septum itself, is present in probably all the genera of Recent and Tertiary Rhynchonellids. Schuchert[6] uses the supposed absence of a cardinal process to separate some Palæozoic and the bulk of Mesozoic and later genera under the Rhynchonellinæ from the early Palæozoic Rhynchotreminæ, in which such a process is present. There is certainly some misunderstanding here.

[1] "An Introduction to the Study of the Brachiopoda, etc.": 47th Ann. Rep. New York State Museum, 1894.

[2] Loc. cit. [3] "Antarctic Fossil Brachiopoda," etc., p. 11.

[4] It is probable that Buckman's species has slender dental plates, for it appears to be synonymous with *H. squamosa* (Hutton), in which they are certainly present. Hutton gave no figure of the latter species, and his description is meagre. An examination of the holotype shows that the species was misunderstood by Tate, who figured a much broader form under that name, and in this Buckman followed him. *H. cælata* (McCoy) is a more coarsely ribbed species, while *H. pyxidata*, Davidson, has discrete deltidial plates.

[5] W. King, *A Monograph of the Permian Fossils of England*, 1850, p. 68, pl. xx, fig. 11. Schuchert speaks of these socket walls as hinge-plates, but this is opposed to the usual convention (cf. H. Woods, *Palæontology Invertebrate*, p. 158, fig. 65, *b*, 1902).

[6] Loc. cit.

In *Hemithyris* there is a small ridge separating the muscular impressions of the dorsal valve which might be described as a rudimentary septum. It does not reach posteriorly to the cardinalia. The latter consists of a pair of socket-ridges which spring from the sides of the valve and project obliquely inwards and upwards, at the same time converging posteriorly nearly to a point. They bear the crural bases on their upper inner margin, fused with them for their whole length. There is no hinge-plate. The cardinal process is transverse and deeply embayed in the middle and is supported by the posterior ends of the crural bases at the sides, but rests in its middle part directly on the umbo of the valve.

In *Frieleia* there is a short low slender mesial septum uniting with the cardinalia. The latter consists of two transversely striated socket-ridges diverging at an angle of about 120°, to which the crural bases are attached along their inner sides. To these in turn are attached two hinge-plates, excavate underneath, uniting mesially and resting on the septum. These hinge-plates differ from those of *Magellania* in possessing an embayed instead of a pointed front. On the hinge-plates there is a small cardinal process.

Ætheia resembles *Frieleia* in the presence of a short septum uniting with the cardinalia, but differs in possessing no excavate hinge-plate. The whole space between the socket-ridges from the floor of the shell as far up as the crural bases is solid, forming an elevated floor, and on this the cardinal process is superimposed.

Cryptopora possesses a long septum which is high near its anterior end, but rapidly lessens in height posteriorly until it unites with the cardinalia. Davidson states that a hinge-plate is present, but his figures do not bear this out. There is certainly a cardinal process superimposed on the end of the septum.

In *Neorhynchia* there is a low thread-like septum, perhaps only comparable to the ridge in *Hemithyris*. Dall has not yet figured this species and does not state whether the septum reaches the cardinalia, and mentions no hinge-plate or cardinal process.

Conclusion.

Owing to the small number of genera represented amongst Recent and Tertiary Brachiopods it is possible to present their major differences in tabular form.

	Beak epithyrid. Dental plates absent.	Beak hypothyrid. Dental plates present.		
	Septum low.	Septum rudimentary.	Septum low.	Septum high.
Dorsally uniplicate.	*Ætheia.*	*Hemithyris* (*Basiola*).		
Ventrally uniplicate.		*Neorhynchia.*		*Cryptopora.*
Non-plicate (? *Cincta* folding).			*Frieleia.*	

III.—Studies in Edrioasteroidea, IX. The Genetic Relations to other Echinoderms.

By F. A. Bather, M.A., D.Sc., F.R.S.

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THE last Study brought out many resemblances between Edrioasteroidea and Asteroidea, much closer than have been recognized even by some who have suggested a derivation of the latter Class from the former. In the present Study it is proposed to inquire whether that hypothesis, or any similar hypothesis, is tenable.

Apart from all other considerations, it is clear that, if *Edrioaster* has in its subvective skeleton reached a stage of development higher than that of the older Palæozoic Asterozoa, then it cannot be regarded as the ancestor of these latter. Further, it is hardly conceivable that the earliest Asterozoa known to us were derived from a genus entirely contemporaneous with them. But the Middle Ordovician Edrioasteroidea had, we know, ancestors in the Cambrian, so that the group was probably in existence in Lower Cambrian times, if not before; and it is among those early forms that the ancestors of the Asterozoa must be sought by any who would support the hypothesis under examination. The descendants of those ancient Pelmatozoa exhibited considerable diversity in regard to locomotion, and we do actually find in the Edrioasteridæ forms that have assumed many Asteroid characters. Surely there may have been other descendants with a tendency to similar structures, but adopting a mode of life in which those structures found larger scope for exercise and development. We know, it is true, that similarity of form is in itself insufficient evidence of blood-relationship; and yet there may be something in Mr. Bergson's argument that the independent appearance of similar structures in different groups points to some identity of initial impulse impressed on a common ancestry.

Time-relations, then, admit the possible derivation of Asterozoa from Edrioasteroidea. But of the three main changes involved in such derivation we have as yet only considered two, namely, the change of function in the ambulacra from nutrient to locomotor, and the elaboration of the mouth from a passive funnel to an active predatory organ. These two changes involve no difficulty, but the third, on which they both depend, is less easy to explain. It is the reversal of the main axis of the body with reference to the substratum; in other words, the transference of the oral pole to the under surface.

In a Pelmatozoön the main axis is vertical, the oral pole is uppermost, and around it are the water-ring (from which proceed the perradial canals), the hydropore, the genital aperture (when present), and the anus; the coil of the gut, when viewed from the oral surface, is dextral or solar. In a primitive Holothurian the main axis is horizontal, the oral pole is anterior, and around it are all the above-mentioned organs except the anus, which is posterior; the coil of the gut is the same. In a regular Echinoid the main axis is vertical, the oral pole is lowermost, and around it is the water-ring, from

which proceed the perradial canals; the hydropore, the genital apertures, and the anus are at the apical pole; the coil of the gut is the same. The orientation of an Asteroid is essentially the same, except that the genital apertures are marginal, and that the gut is not obviously coiled; the relative positions of the anus, when present, and of the madreporite are, however, in accordance with a solar coil (see *Treatise*, 1900, pp. 21 and 34), and such a coil does appear in early stages of development (Gemmill, 1914). An Ophiuroid differs from an Asteroid in the entire absence of anus, and in the position of the hydropore on the oral surface.

Therefore, the passage from a pelmatozoan to an echinoid or asteroid type involves: (1) the translation of the mouth, the water-ring, and the proximal ends of the perradial water-vessels, from an upper to an under position; (2) the translation of the hydropore, the anus, and, to a less extent, the genital apertures, from the oral to the apical surface; (3) the retention of the solar coil of the gut when viewed from the oral surface. Two modes of effecting the passage are conceivable. The first demands (*a*) the closure of the original mouth and the breaking out of a new one at the opposite pole; (*b*) the corresponding sinking of the circumœsophageal water-ring and the evolution of an entirely fresh set of perradial water-vessels starting from this new oral pole; (*c*) the reversal of the coil of the gut; it does not demand any essential alteration in the position of anus, madreporite, or genital apertures, or in the normal position of the theca as a whole. The second mode demands (*a*) the turning upside-down of the whole theca; (*b*) the migration of hydropore and anus along the posterior interradius towards the aboral pole, and, as a consequence, the elongation of the stone-canal; (*c*) a change in position of the genital apertures; it does not demand any alteration in the original mouth, in the coil of the gut, or in the other relations of the water-vascular system. The position of the genital apertures may be neglected, for in either case there must have been an entirely independent evolution of pentamerism in the gonads, and probably the bursting through of a fresh set of apertures. However this may be, there is little doubt but that the second mode of passage is the more in accordance with general echinoderm evolution. The migration of the hydropore may be paralleled in holothurians, and the migration of the anus in crinoids and echinoids. There remains only the initial step—the overturning of the whole theca.

It is clear that a change of this magnitude was no sudden one. As Professor MacBride has happily remarked, "No animal ever went to bed with one set of habits and woke up in the morning with another." In the absence of direct evidence we can only speculate, but our speculations must be controlled by two distinct sets of facts and principles. The changes imagined must be consistent, first, with the ordinary processes of life and the general character of such changes in the Echinoderma, secondly, with the facts of development in the recent Echinoderma concerned.

A possible mode of origin of Asterozoa from some early Edrioasteroid has been suggested briefly in the *Encyclopædia Britannica*, Supplement, vol. 27, p. 623 (July, 1902) and Eleventh Edition, vol. 8, p. 877

(Feb., 1911), and more fully expressed in "What is an Echinoderm?" (Journ. London Coll. Sci. Soc., vol. 8, pp. 21–33, May, 1901; Italian edition, Oct., 1901). This hypothesis has been criticized on the ground of the structure of certain fossils by Mr. W. K. Spencer (1904), who, however, now recognizes that he "overstated" his "case . . . It is not difficult to imagine a more primitive Edrioasteroid which would show, at any rate, near relationships with the ancestral Eleutherozoa" (1914, p. 6). More weighty objections have been raised by Professor MacBride and Dr. Gemmill on the ground of their admirable observations on Asteroid embryology. But while the hypothesis which they themselves adopt, as expressed in Professor MacBride's *Textbook of Embryology: Invertebrata* (1914, pp. 560–5), is difficult of acceptance, on the other hand some of their own recent observations seem actually to support the hypothesis which they reject. Let us consider these conflicting views more closely.

We now agree on many points of fundamental importance. We agree, namely, that the ancestral Asterozoa were attached by a stem homologous with that of the Crinoidea in so far as it was derived from the same portion of the larva. We agree that the ancestral Asterozoa fed by a subvective system of ciliated grooves. We agree that radiate symmetry was—in Eleutherozoa as in Pelmatozoa—a consequence of this mode of life. It is admitted that processes subsequent to the fixation of the bilaterally symmetrical ancestor by its anterior end eventually brought the stem: (*a*) in Crinoidea, to an aboral position outside the water-ring; (*b*) in Asterozoa, to an excentric oral position within the water-ring. We even appear to be agreed as to the changes that produced the plan (*a*).

The difference arises with regard to the number and order of the steps that produced the plan (*b*).

Whereas some of us have expressed the opinion that the ancestors of the Eleutherozoa passed through a true pelmatozoan stage, with mouth uppermost, and that to this stage the Echinoderma owe their coiled gut and radiate symmetry, MacBride and Gemmill hold that "the Echinoderm stock became split into two stems" shortly after the ancestral Dipleurula had become fixed by its prae-oral lobe, and after the organs of its left side had begun to grow more rapidly than those on the right, but "before the hydrocoel was a closed ring, and before radial symmetry was completely attained". From such a stage, they maintain, the primitive Asterozoön evolved immediately and directly, with its mouth turned towards the sea-floor, so that the left hydrocoel, as it developed into a hydrocircus, grew round the stem, which was therefore on the oral face; and it was while the creature was so supported that radial symmetry was acquired. Figures illustrating this view are given in MacBride's classical paper on "The Development of *Asterina gibbosa*" (1896, Quart. Journ. Micro. Sci., vol. 38, pl. 29, figs. 157–9) and are reproduced in his *Textbook of Embryology* (1914, p. 563). It should be noted that in the *Cambridge Natural History* (1906, Echinodermata, p. 621) a mistake crept into the diagram of the primitive Pelmatozoön, in that the gut was given a contrasolar coil.

It is, presumably, the position of the stalk within the hydrocircus,

as observed in the larva of the modern Asteroid, that forms the basis both of MacBride's own hypothesis and of his criticism of the so-called Pelmatozoic Theory. It may, however, be pointed out that in the history of both the Echinoderm race and the Asteroid individual, the hydrocircus begins as a hydrocoel crescent; also that in the larval Asteroid the stalk is on that side of the mouth where the crescent is open, and is not within the circumoral nerve-ring. The passage of the stalk in either direction would therefore be quite easy at a far later period of race-history than that to which Professor MacBride feels compelled to restrict it.

Now the two remarkable features of Echinoderm morphology which any hypothesis should seek to explain are, first, the hypertrophy of the left side with the correlated torsion, secondly, the radiate (normally quinqueradiate) symmetry.

The first of these, which affords the chief reason for the Pelmatozoic Theory, is frankly left unexplained by Professor MacBride. He writes: "It can only be described as an idiosyncrasy of Echinoderms that bilateral symmetry is unstable, and that, therefore, radial symmetry was arrived at by the overgrowth of the organs of the left side, etc." (1914, *Embryology*, p. 562). Similarly Professor Hérouard in an interesting note (Jan., 1915, Bull. Inst. Océanogr. No. 301) describes this "idiosyncrasy" as a hemiplegia, "un phénomène tératologique . . . dont nous constatons l'apparition sans malheureusement pouvoir en expliquer les causes." "On peut dire, que la série des êtres [échinodermales] que nous considérons comme représentant l'évolution normale, n'est dans sa totalité qu'une branche de la tératologie représentant la série des monstres nés viables et capables de se reproduire."

On the supposition that the tendency to this monstrous paralysis of the right side arises from something in the larva itself, the only explanation hitherto suggested has been that of Dr. Fr. Meves (1912, Arch. mikr. Anat., vol. 80, pp. 81–123). Having observed in *Parechinus miliaris* that the middle-piece of the spermatozoön passes at the first cleavage of the spermovum into one of the two blastomeres, he supposes that the substance of the middle-piece is, in the course of successive cleavages, eventually confined to that part of the pluteus which becomes the sea-urchin, and that those parts of the pluteus which disappear consist of cells which, in the course of cleavage, have received none of the middle-piece substance. This hypothesis is merely a succession of uncorroborated assumptions, and even if we could for a moment accept the supposition that the male characters (Vererbungspotenzen) were confined to the embryonic echinoderm, the remaining cells of the larva being merely trophoblast, we should not thereby explain the peculiar changes of symmetry.

Reducing it to its simplest terms, Hérouard (1915) describes the change as the replacement of the original binary axis by a secondary quinary axis. In Asteroidea and Echinoidea, he says, this quinary axis is at right angles to the binary axis. In Ophiuroidea and Holothurioidea, which both MacBride and Hérouard regard as derived respectively from Asteroidea and Echinoidea, the quinary axis is inclined to the binary axis and ends by almost coinciding therewith.

In Pelmatozoa also the quinary axis comes almost to coincide with the binary axis, but its direction is reversed.

Of these changes the Pelmatozoic Theory offers an explanation which, whether correct or no, is at any rate less transcendental than appeals to "idiosyncrasy", invisible "Vererbungspotenzen", or "hémiplexie tératologique". By this theory the relations of the axes of symmetry emphasized by Hérouard are interpreted in accordance with the life-history. The Dipleurula becoming fixed by its anterior end, the mouth passes to the opposite pole, and thus arise the Pelmatozoa with axis vertical and in a reversed direction to that of the Dipleurula. The change from these to the earlier Eleutherozoa is complicated by the retention of the stalk; the whole oral surface bends over, and the quinary axis is at right angles to that of the Dipleurula. In the later Eleutherozoa the process is carried further, and the quinary axis returns almost to the position of the original binary axis.

The associated changes in the torsion of the gut and in the movements of the coelomic cavities, loosely moored in the body-fluids, are described in the *Treatise on Zoology* (1900), and in the writings previously referred to (1901, 1902, 1911). We pass them by for the moment to consider the second morphological feature, the radiate symmetry.

Radiate symmetry arises and is maintained when an organism is evenly related to its environment on all sides. This happens in the case of fixed organisms, when they gather their food from all quarters irrespectively, by leaves or by tentacles or by ciliated grooves; in the case of free organisms, when they move indifferently in the direction of any radius. This evenness of relation may be interfered with from without or from within: from without, especially in the case of a fixed organism, when the situation is such that currents of air or water, or rays of light, beat on it mainly from one-side; from within, by some change in the organism itself whereby its relation to the environment is altered, as when a free organism takes to moving in the direction of a particular radius (cephalization), or when a fixed organism for some special purpose (e.g. excretion) enlarges one of its unpaired asymmetrically situate organs. The Echinoderma, which, even in the most specialized Ophiuroid, never have attained an absolute radiate symmetry, present us with examples of almost every conceivable departure from such symmetry in forms both free and fixed.

Now Messrs. Gemmill and MacBride fully accept these views as to the origin of radiate symmetry, and believe with me that the free Echinoderms owe the radiate arrangement of their organs to inheritance from a fixed ancestor, which acquired that arrangement in consequence of the radiate extension of its food-catching organs. But the mode of fixation which they postulate, namely by a stalk asymmetrically placed on the oral face, is not one calculated to lead to such symmetry. Not merely does it appear exceedingly improbable that an animal feeding solely by ciliated grooves should ever have assumed or maintained such a position, but even if it did so it would not have been evenly related to the environment on all sides. In those Pelmatozoa that have assumed a similar position with reference to

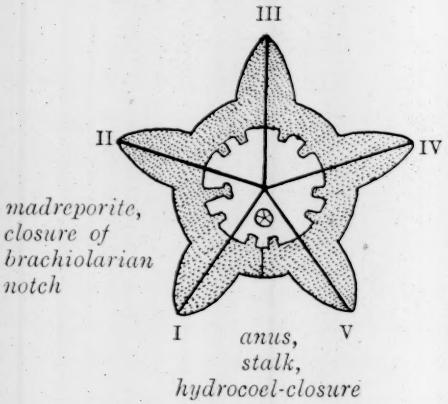


FIG. 1.

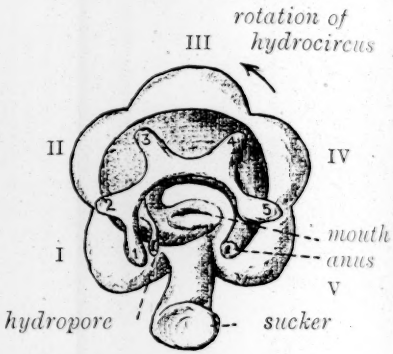


FIG. 2.

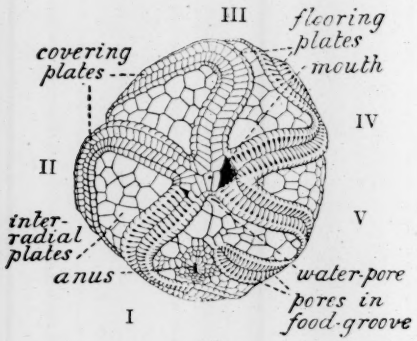


FIG. 3.

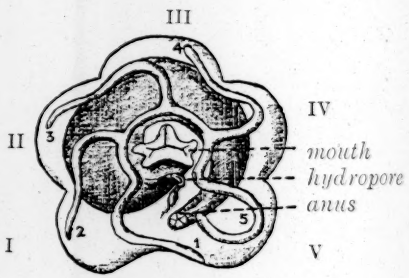


FIG. 4.

FIG. 1.—Diagram to illustrate MacBride and Gemmill's numbering of the rays in Asterias. The view is from the oral side. The position of the anus is that occupied by it in the adult, but it opens on the apical side.

FIG. 2.—Diagram of Asterias at the beginning of metamorphosis, based on the figures and description of Gemmill. The view is from the oral side, on which side the anus opens at this stage. The numbers I–V correspond with II, III, IV, V, I in Fig. 1. Hydrocoel pouches are numbered 1–5.

FIG. 3.—Oral face of *Edrioaster bigsbyi*. The numbers I–V correspond with those in Figs. 2 and 4, but not with those in Fig. 1.

FIG. 4.—Diagram to show the supposed relations of water-vascular system and gut in young Edrioaster. The view is from the oral side. The numbers I–V correspond with those in Fig. 2. The ends of the hydrocoel pouches 1, 2, 3, 4 enter rays 5, 1, 2, 3 respectively, and in this regard make those rays correspond with rays I, II, III, IV of Fig. 1. The hydropore leads into the stone-canal, and probably into a genital duct.

the attachment (e.g. Calceocrinidae) a strong secondary bilateralism has been superimposed on the pentamerism, and has generally quite obscured it. Pentamerism could never have arisen under such conditions.

Another objection to this imaginary ancestor springs from those sanitary principles that have proved so useful in elucidating the morphology of extinct Pelmatozoa (see especially "Caradocian Cystidea from Girvan", §§ 232, 583, 591; Trans. Roy. Soc. Edinburgh, vol. xlix, part 2, No. 6, 1913). The guiding idea is that the excreta should be removed as far as possible from the food intake and the respiratory organs, and at the same time in such a position that they will be carried away by currents. Now the imagined primitive Asterozoön contravenes those principles, because mouth, vent, and hydropore were certainly all on the oral face, and yet we are to suppose that face turned downwards towards the attachment.

Even if the ancestral Asterozoön, as imagined by Messrs. Gemmill and MacBride, could scarcely have been viable, it does not follow that the Pelmatozoic conception of the ancestor is any more in harmony with known facts and principles. Indeed, it is asserted that the facts of recent Asteroid embryology render it inadmissible. Let us consider some of these "very serious ontogenetic difficulties".

A reader who accepts the orientation of the rays adopted in Gemmill's paper on *Asterias rubens* (Phil. Trans., 1914), will speedily meet with stumbling-blocks.

In the larval stages of that form and of several others, the anus, the stalk, and the hydropore all lie between the horns of the hydrocoel crescent. The hydrocircus is formed by the closure of the horns in that interradius. It is therefore from this point that MacBride and Gemmill, very reasonably, start their numbering of the hydrocoel pouches. As the first pouch, they take that which lies towards the anterior end of the bilateral larva: if the embryo star be viewed with the mouth upwards, this is the pouch that forms the left horn of the crescent, so that the remaining numbers follow on in a solar direction. Those authors use the Roman numerals I–V, but, for a reason that will appear presently, it will conduce to clearness if for these particular structures we provisionally use the Arabic figures 1–5. The rays of the star with which these hydrocoel pouches eventually become associated are similarly numbered I–V by MacBride and Gemmill, i.e. ray I corresponds with pouch 1, II with 2, and so on. Thus, for the adult structure, Dr. Gemmill arrives at the annexed diagram (Fig. 1), which is copied from that in his memoir, but turned upside-down so as to render it more easily comparable with the arrangement in Pelmatozoa. Here the adult anus lies in interradius I/V, which marks the "Asterid plane" of Cuénot. It is not in this interradius but in the adjoining one (I/II, solar in oral, contrasolar in aboral aspect) that the madreporite and stone-canal of the adult are found. The latter interradius also corresponds with the brachiolarian notch, and bears a most important relation to the sagittal mesentery of the larva, and to the epigastric mesentery of the developing star.

In all the early Pelmatozoa, on the other hand, the hydropore, the anus, and presumably the closure of the hydrocoel are normally in a single interradius, which bears a definite relation to the branching of the rays, and therefore serves as the starting-point for their numbering.

Now since it is not immediately obvious how either of these sets of organs can have jumped over the intervening radius (I), this seems rather a fundamental difference. It is, I believe, capable of explanation on the Pelmatozoic theory; but before reverting to that let us consider some further facts of embryology.

First, note that in the recent adult starfish both anus and madreporite are on the apical surface. In the early stages, however, they are on the oral surface. Therefore they have migrated. Now while the madreporite remains between the same rays of the star as the original hydropore lay, the anus has changed. We are, however, unable to trace its migration because there is a gap due to closing of the larval intestine and the formation of a new rectum and proctodaeum. This fact alone should be enough to suggest that the evolution of the Asteroidea from the fixed Dipleurula cannot have been so simple and direct as claimed by Gemmill and MacBride and as represented in the latter's diagrams.

As regards the madreporite, the application of these facts to phylogeny is clear, because in the fossils we can trace the historical passage of the madreporite between the rays from an adoral, or oro-marginal, position to an adapical position (see Spencer, 1914, Mon. Brit. Pal. Ast.).

The anus is so obscure, if not absent, that its passage is less easily traced in those fossils. According to C. Schuchert,[1] "The only Paleozoic form in which an anal opening may exist visually is [the Ordovician] *Hudsonaster*. Here it is on the [adapical] disk between the central plate and the madreporite" (p. 13), apparently, then, still in the hydropore interradius; but the anal nature of the appearance is very doubtful (p. 39). In other fossil Echinoderms, however, the migration of the anus can be traced and is observed to follow the presumed line of the coiled gut. That is just what happens in the developing starfish: the coil of the gut shortens and the anus is consequently pulled in a contrasolar direction (as viewed from the oral pole), i.e. from the madreporite plane into the Asterid plane. Though the coil of the gut is thus obscured in Asteroidea, it is important to recognize that it really is of the same nature as in other Echinoderms (see *Treatise on Zoology*, 1900, p. 34).

Consequently, from the embryological and anatomical facts now placed in so clear a light by Dr. Gemmill, we can readily imagine how and why the anus, in its phylogenetic passage from the oral to the aboral surface, followed a course which was not straight but curved so as to bring it into the interradius where it now lies. Further we see that, whereas the anus was exposed to two forces or tendencies, of which its present position is the resultant, the madreporite was subject to only one, namely the tendency to pass

[1] "Revision of Paleozoic Stelleroidea," U.S. National Mus., Bull. 88, 20 March, 1915. This valuable work appeared some months after these paragraphs were first written.

from oral to apical along the straight plane of the stone-canal. Hence it did not change its interradius.

As was shown in "What is an Echinoderm?" these movements are precisely those which would naturally take place on the hypothesis of the origin of Asteroids from such a Pelmatozoön as *Edrioaster*. That hypothesis makes these movements very simple and inevitable, but the converse conclusion does not necessarily follow: the conclusion, namely, that because these movements must have taken place, therefore the ancestor of the Asteroids was an Edrioasteroid. All that is claimed is that the facts thus far are fully consistent with such a conclusion.

We turn now to the next difficulty: the position of the plane of closure of the hydrocoel. As already explained, this plane is placed by MacBride and Gemmill between their rays I and V, i.e. in the Asterid plane of Cuénot (my interradius IV/V).

In the primitive Pelmatozoön, so far as can be inferred from the embryology of *Antedon* and the anatomy of early forms, the closure of the hydrocoel was in what I have termed the M plane (see *Treatise on Zoology*, 1900, p. 20). This corresponds with MacBride and Gemmill's interradius I/II (my I/V).

It is important to notice here that in an Asteroid larva (*Bipinnaria asterigera*) described by Bury, the closure does still take place in the M plane (1895, Quart. Journ. Micr. Sci., vol. 38, p. 65).

Apart from the hydrocoel and its extensions, the food-grooves of Pelmatozoa (which are the initiators of the rays) are bilaterally symmetrical about the M plane. Therefore we are not surprised to find that in Asteroids this same plane is that in which the brachiolarian notch occurs and closes, and that the rudimentary rays (apart from the hydrocoel) are similarly bilaterally symmetrical about that plane (Fig. 2). Other relations of this plane have already been mentioned (see Gemmill, 1914, Phil. Trans., p. 277).

The M plane, therefore, is as fundamentally important a plane for Asteroidea as it is for Pelmatozoa. The Asterid plane is a plane of superimposed symmetry, due to the migration (*a*) of the anus, (*b*) of the hydrocoel-closure. One speaks of the "migration" of the hydrocoel-closure because it cannot be imagined that the closure takes place in a different part of the hydrocircus itself. If we postulate any homology whatever with Pelmatozoa, we can only explain the difference of position by supposing that the whole hydrocoel has shifted round. The extent of the shifting would be one-fifth of a circle, i.e. 72°; and the direction of the shifting, as viewed from the oral face, would be contrasolar. Such shifting need not involve the hydropore, with which the hydrocoel has only a secondary connection.

Now we know very well that, in those Asteroids where the hydrocoel-closure is in the Asterid plane, just such a shifting or torsion does take place in the early stages of metamorphosis. To quote Gemmill (1914, Phil. Trans., p. 251), "the disc undergoes torsion through about 75° in the (starfish) horizontal plane, counter-clockwise as viewed from the sucker." It must be remembered that the development of the lobes of the hydrocoel is quite independent

from that of the arms, and that only later on do the two sets become apposed or harmonized. The accounts given by the embryologists seem to prove that in certain Asteroids there actually is such a shifting of the whole hydrocoel that each lobe of it becomes applied, not to the ray to which it would (especially on any homology with Pelmatozoa) naturally belong, but to the neighbouring ray, just as though one were to twist a clock-face backwards, so that when the clock struck twelve the hands should point to twelve minutes past two (i.e. one-fifth of the clock-face).

This interpretation is confirmed by the exception ; for in Bury's *Bipinnaria,* where the hydrocoel closes in the M plane, the fusion of the main hydrocoel lobes with the rays "is effected", says Bury, "without that rotation of the two series of organs noticed by Ludwig in Asterina" (1895, p. 68).

It seems legitimate to infer that in some remote ancestor of the Asteroids the closure of the hydrocoel took place in the M plane, and that the lobes 1 to 5 corresponded with the rays numbered I to V in the Pelmatozoa, but numbered respectively II, III, IV, V, I in the adult Asteroid by MacBride and Gemmill.

Why this torsion took place in some Asteroids we do not know. It may have been connected with the migration of the anus and the dragging of the mesenteries. That is a point which the embryologists do not as yet seem to have discussed.

It was, however, pointed out in "What is an Echinoderm?" that if any Asteroids were evolved from a pelmatozoön in which the food-grooves had a strong contrasolar curve (as in *Edrioaster bigsbyi*), then some such contrasolar torsion of the oral region through 72° would naturally accompany the straightening of the rays. Examination of Text-figures 3 and 4 will at once make this clear. This hypothesis works quite well so far as the hydrocoel is concerned, but seems to create a difficulty with regard to the hydropore, which, one might suppose, would also have been involved. We have to remember, however, that the hydropore and stone-canal did not necessarily accompany the hydrocoel, and when the madreporite had attained the aboral surface and escaped the influence of the rays, it might have been pulled back into its original interradius by the stone-canal.

Any exceptions, such as Bury's *Bipinnaria*, would, on this same hypothesis, be readily accounted for by supposing those starfish to derive from an Edrioasteroid like the Cambrian *Stromatocystis*, in which the rays have not acquired a curvature.

To consider the possible relations of the Pelmatozoa (Edrioasteroid or other) to the Echinoidea would unduly prolong the argument. Those to whom the present paper is intended to appeal agree with me that the Echinoidea no less than the Asteroidea must have had a fixed ancestor, and Professor MacBride, for one, would derive all Eleutherozoa from the Asteroid stem. If we can but agree as to the Asteroid ancestor, the rest follows.

The essential difference between us is that Messrs. MacBride and Gemmill believe the Asteroid to have evolved directly, mouth downwards, from the Dipleurula, whereas I would insert a true Pelmatozoic stage.

So far as the change in mode of life is concerned, their hypothesis is no easier than mine. Professor MacBride has made a number of ingenious suggestions, chiefly dependent on "the fundamental distinction which obtains at the present day between the habits of Eleutherozoa, which in the majority of cases are scavengers, devouring dead animals and organic detritus lying on the bottom, and those of Pelmatozoa, which to this day feed on Plankton captured by currents produced by the cilia covering their tentacles" (1914, *Embryology*, p. 564). Now that Dr. Gemmill has broken down the barrier of this "fundamental distinction" the hypotheses based on it lose much of their probability.

If we imagine an Edrioasteroid with loose attachment, liable to be overturned by currents, just as we know that individuals of *Stromatocystis* were overturned, then all we have to suppose is that some of the overturned individuals were able to survive the accident. This they would be able to do if they had fairly well-developed podia, such as are indicated by the anatomical evidence. Even without the overturning, the podia of such genera as *Edrioaster* and *Dinocystis* might have subserved locomotion; for in them the ends of the subvective grooves were brought into almost direct contact with the sea-floor. Indeed, it is hard to see how locomotion could have been avoided.

As for the alleged directness of individual development (which, as already pointed out, is not direct in some important particulars), this may well be more apparent than real. If it be direct, we are thrown back on 'idiosyncrasy' and 'hemiplegia' and misfits 'somehow displaced'. If, on the other hand, the stalk represents the last trace of a former pelmatozoic stage, we have to imagine that the greater part of that stage has been cut out. But what is more natural? In Ophiuroidea the fixed stage is omitted altogether. In Asteroidea it is not omitted but condensed. The later stage, in which the mouth is already directed downwards, has been pressed back so as to eliminate the supposed stage during which it passed upwards. The preservation of that stage in the ontogeny would have been a useless waste of energy.

Dr. Gemmill says that my view introduces "very serious ontogenetic difficulties". I am unable to see that the main ontogenetic difficulties are any better explained by the Gemmill–MacBride theory, which in its turn seems to me to introduce a fresh set of phylogenetic difficulties.

IV.—The Moraine Walls and Lake Basins of Northern Italy.

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

THE present paper is the outcome of a number of visits which, during a prolonged professional residence in Italy, I paid to Piémont, Lombardy, and the Italian lakes, and in the course of which I became familiar with the glacial phenomena and the lake basins along the southern base of the Alps.

It is forty years—1874 to 1876—since the 'Moraine Amphitheatre', or series of moraine walls at the foot of the Italian Alps,

suddenly came into prominence through the discovery, chiefly by Stoppani, of several glacial clay, sand, and gravel deposits in the vicinity of Como, which contained marine shells, and therefore demonstrated the presence of the sea in contact with the Alpine glaciers. Stoppani's conclusions, expounded in two brilliant memoirs,[1] were endorsed not only by his Italian confrères, Spreafico[2] and Sordelli,[3] but also by distinguished geologists north of the Alps, notably by Désor of Neuchâtel,[4] Renevier of Lausanne,[5] and Rutimeyer of Bâle,[6] the revealing memoirs more especially of the two last-named being models of classical and closely reasoned exposition. Since then the subject has been enlarged upon chiefly by discoveries of interglacial deposits in various sub-Alpine valleys debouching into the Lombardy plain, and more recently Penck and Brückner have dealt with it from their point of view in their latest monumental work,[7] whose salient features have been summarized by G. W. Wright.[8] But the evidence adduced by the various Italian and other writers, including Penck's somewhat laboured endeavour to work out his four glaciations for the Alps *en bloc*, is as yet so conflicting that it is almost refreshing to turn to the earlier and more conclusive views of Stoppani and his contemporaries as a point of departure for considering the subject *mutatis mutandis*, in order to arrive at some independent conclusions from personal observation.

I. The Moraine Walls.

As will be seen from the sketch-map, Sheet No. 1, Fig. 1, the belt of double, in many places triple concentric moraine walls which fringes the southern base of the Alps, forms roughly a semicircle extending from Cuneo in the south of Piémont to Lake Garda in Lombardy, a distance of about 400 kilometres, and from the last-named point to the Frioul, another 200 kilometres. The most striking feature of this belt consists not only in its remarkable extent but in the enormous accumulations of glacial material, compared with which the morainic deposits north of the Alps, notably in Switzerland, almost sink into insignificance. The moraine walls were all formed, like so many bars, in front of the exits of the principal valleys. Thus, near Cuneo we find the terminal moraine of the Stura glacier; west of Savigliano, that of the Po (Monte Viso); at Rivoli, near Turin, that of the Dora

[1] Stoppani, "Il mare glaciale ai piedi delle Alpi": Rivista Italiana, Agosto, 1874. "Sui Rapporti del terreno glaciale col Pliocenico nei dintorni di Como": Atti Soc. Ital. di Scienze naturali, Aprile, 1875.

[2] Spreafico, "Conchiglie marine nel terreno erratico di Cassina Rhizzardi (Fino, Prov. di Como)": Atti Soc. Ital., 1874.

[3] Sordelli, "La Fauna marina di Cassina Rhizzardi, Fino": Atti Soc. Ital., 1875.

[4] Désor, *Le Paysage morainique et son origine glaciaire*, Neuchâtel, 1875.

[5] Renevier, "Rélations du Pliocène et du Glaciaire aux environs de Côme": Bull. Soc. Géol. France, sér. III, tome iv, 1876.

[6] Rutimeyer, *Ueber Pliocän und Eisperiode auf beiden Seiten der Alpen*, Bâle, 1876.

[7] Penck and Bruckner, *Die Alpen im Eiszeitalter*, 1909.

[8] G. W. Wright, *The Quaternary Ice Age*, 1914.

Riparia (Mt. Cenis); at Ivrea that of the Dora Baltea (Mt. Blanc and Mt. Rosa); at the lower end of Lakes Maggiore and Varese, that of the Ticino and Toce (St. Gothard and Simplon); near Como and Lecco that of the Adda; at the lower end of Lake Isco that of the Oglia; and at Lake Garda the terminal moraine of the Mincio glacier.

The most formidable of these moraine walls are those of Ivrea and at the lower ends of Lakes Maggiore, Como, and Garda. South of Ivrea the Monte Rosa glacier, descending through the lower Dora Baltea Valley, has left two stupendous marginal moraine walls, the "Serre" of Andrate and Brosso, which reach a height of no less than 450 metres above the present river-level and, with the frontal moraine broken up into hillocks and interspersed with morainic lakelets, form a circumference of at least 50 kilometres. Again, south of Lakes Maggiore and Varese, the concentric moraine belts of the Ticino and Toce glaciers extend to 10 kilometres from the lake-end, with a circumference of 50 kilometres and a height of 150 metres above Lake Maggiore. South of Como the moraine deposits form, in a distance of barely 10 kilometres, three separate concentric ridges about 20 kilometres in length, rising to 152, 157, and 165 metres above the level of Lake Como. Similarly, at the lower end of Lake Garda, the moraine walls extend in concentric semicircles and an extraordinary agglomeration of morainic hills 12 kilometres into the Lombardy plain, with a circumference of at least 30 kilometres, and rising to 23, 62, and 141 metres above the lake-level.

The points where marine shells were found embedded in glacial deposits are situated about 6 kilometres south and north-west of Como; the former near Fino, on the second of the three concentric moraine ridges, about 160 metres above the present lake-level, and the latter between Chiasso and Mendrisio in the Breggia Valley, by which the former Lugano fiord communicated with that of Como.[1] The most northerly of the latter deposits is that of Pontegana, near Balerna, about 90 metres above the present lake-level, which, being glacial clay, corresponds to similar deposits near Varese and to others in the Ivrea district. In Lombardy the shell-bearing deposits rest directly on Pliocene marl and are overlain by morainic material of sand, gravel, and conglomerate, known as ceppo and ferretto, while in Western and Southern Piémont many of the glacial deposits exhibit intermediate fluvio-glacial alluvia, whose origin was at the time a subject of keen controversy between Stoppani and Gastaldi. These alluvia are, in fact, the southern equivalent of the "alluvion ancienne" and Deckenschotter north of the Alps, and, as such, the product of a pre-maximum glaciation which in Upper Piémont, but not in Lombardy, reached to the foot of the Alps. As regards the stupendous Moraine Amphitheatre of Piémont and Lombardy as a whole, it can only be the product of the maximum glaciation, while any pre-maximum, as also the post-maximum or last glaciation, probably did not descend much beyond the heads of the present lakes, or, roughly, beyond a limit 30 to 40 kilometres distant from the Lombardy

[1] Most of these deposits are now obliterated, but ample specimens of the marine shells are preserved in the Geological Museum of Milan.

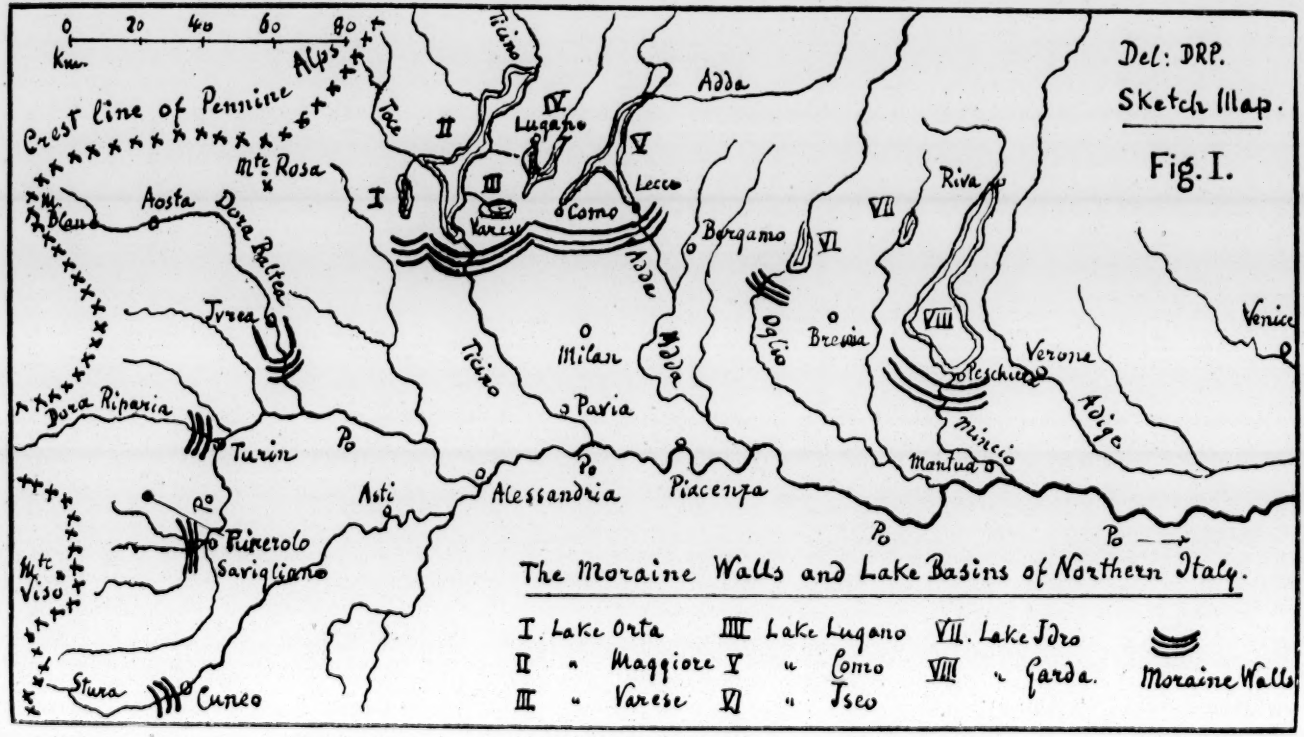
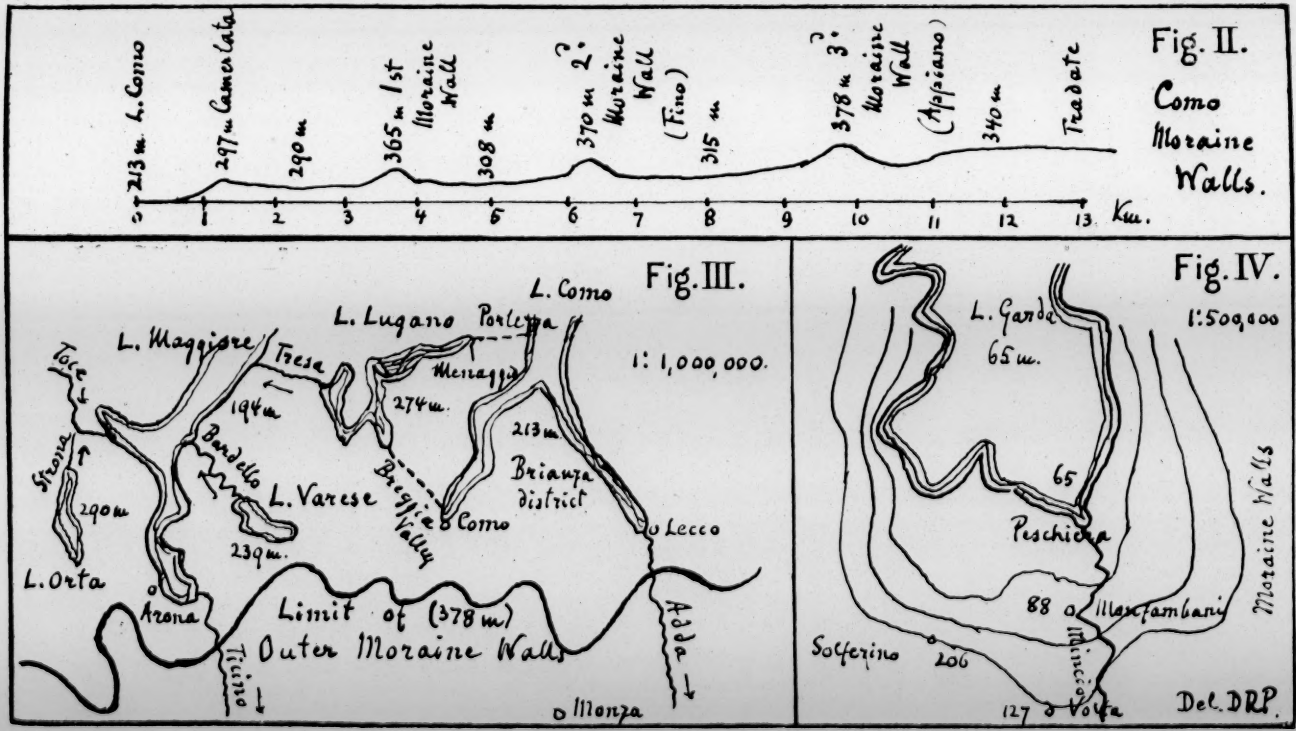


FIG. I.—Sheet No. 1. Sketch-map of Northern Italy.



FIGS. II, III, IV.—Sheet No. 2. Moraine Walls.

plain.[1] The extreme limit of the maximum glaciation, as indicated by the outermost moraine walls 10 to 12 kilometres south of the lower ends of the Lakes Orta, Maggiore, Como, and Garda, is shown in Sheet No. 2, Figs. II, III, and IV.

II. The Glaciers and the Sea in the Po Valley.

The maximum glaciation south of the Alps presents a striking contrast to that on the north in that it was marked by a uniform general advance of more or less self-contained glaciers of the fan or Piémont type, which invaded the Po Valley to a distance of 10 to 12, in the case of the Dora Baltea (Ivrea) glacier even 20 kilometres, while north of the Alps the glaciers spread all over the Swiss lowlands and deposited their terminal moraines even beyond. Thus the maximum length of the southern glaciers, measured from the crest-line of the Alps to their terminal moraine walls, does not exceed 100 kilometres, while on the north the Rhone and the Rhine glaciers, extending beyond the Jura and Lake Constance respectively, reached a length of 300 kilometres, or three times as much. Inversely, the quantity of material carried and deposited by the southern glaciers having an average fall of 1 in 100, was immensely greater than that of the northern glaciers, the average fall of which was only about half the above. Hence the enormous accumulations of glacial material in Piémont and Lombardy, where, moreover, the glaciers on emerging from the valleys were arrested by the sea as an effectual barrier to their further advance into the Po Valley. This Upper Pliocene sea, an arm of the Adriatic, must have lasted well into the Pleistocene period, and the glaciers washed by it must have been stationery for a very long lapse of time, as is shown by the double and triple concentric frontal moraine walls, each of which marks a long halt in the slow retreat of the ice.[2] No less certain is it that the sea must have been at a level much higher than the present Po Valley, and higher even than the present levels of the lakes, for the Pontegana marine shell-bearing deposit in the Breggia Valley north of Como is at 300 metres altitude, which is 87 metres above Lake Como, 197 metres above Milan, and 240 metres above the Po at Piacenza, while the Fino deposits south of Como are at an altitude of even 370 metres. It is therefore obvious that at the advent of the maximum glaciation, arms of the sea reached as far as the fjords which constitute the present lake basins—a phenomenon which has an important bearing on the age and origin of the lakes themselves.

[1] The principal localities of interglacial deposits between Lakes Maggiore, Lugano, and Garda, and beyond are the following: at Re, in the Vigezzo Valley, east of Domo d'Ossola; at Calprino, near Lugano; at Leffe and Gandino in the Seriana Valley, north of Bergamo; at Pianico in the Oglio (Lake Isco) Valley; at Valmarino in the Piave Valley, north of Treviso; in the Tagliamento Valley, north of Udine; and in the Isonzo Valley, north of Gorizia.

[2] It is a striking feature that, of the moraine walls, those of the Como district are continuous, because the Adda eroded its bed marginally from the Lecco arm of the lake, whereas the rivers of Ivrea, Lake Maggiore, and Lake Garda (Dora Baltea, Ticino, and Mincio) found their exit more through the centre of the frontal moraines, which are therefore broken up into agglomerations of hillocks.

III. The Lake Basins.

The following table gives the altitudes and dimensions of the principal six Italian lake basins, which, it will be observed, lie in a zone similar to that of the five Swiss lake basins north of the Alps.

Lake.	Altitude. m.	Length. km.	Mean Width. km.	Area. sq. km.	Greatest Depth. m.	Exit River.
Orta . . .	290	12	2	20	300	Strona [a]
Maggiore . .	194	60	4	212	372	Ticino
Varese . .	239	9	2	14	380	Bardello [b]
Lugano . .	274	22	2	83	300	Tresa [c]
Como and Lecco	213	48	3	144	409	Adda [d]
Isco . . .	201	25	2	62	600	Oglio
Garda . .	65	55	6	490	346	Mincio

[a] Drains into Toce, affluent of Lake Maggiore ; [b] drains into Lake Maggiore ; [c] ditto ; [d] exit through Lecco arm.

It will be seen that not one of these lakes reaches the altitude of 300 metres, which, as previously shown, is that of the marine shell-bearing deposit a few kilometres north of Como, nor the altitude of the Fino deposits (370 metres) on the second moraine wall south of Como. The sea in the Po Valley must therefore have communicated with the fjords at a level much higher than that of the present lakes.

The question of how and when the present lakes were formed is obviously and closely allied with the retreat of the sea from the Po Valley. Désor [1] held that from the time of the glaciers coming into contact with the sea the littoral of the Lombardy and Piémont plain was gradually raised ; but this would only account for the high level of the Fino and the other marine shell-bearing deposits. It appears much more likely that a simultaneous lowering took place on the one hand in the floor of the Po Valley,[2] while the sea gradually receded, and on the other along the base of the Alps, which converted the fjords into lakes in addition to the fjords being choked by the moraine bars of the retreating glaciers. The formation of the lakes would, therefore, be due to the same two concurrent causes which operated in the formation of the lake basins north of the Alps—a zonal flexure and a moraine barrier behind which the river valleys or fjords became lakes during the recession of the glaciers.

The cross-section of the triple moraine walls south of Como shown in Sheet No. 2, Fig. II, which Rutimeyer gave for another purpose in his memoir already quoted, exhibits a striking reverse dip from the outermost wall to Lake Como of no less than 165 metres. The third moraine wall, which rests upon considerably bent strata of Molasse, thus constitutes, in my view, the anticline of the flexure whose syncline to the north follows the deepest points of the lakes, while the syncline to the south lies along the lowered floor of the Po Valley. The conditions in respect of Lake Maggiore and of Lake Garda are precisely similar, the reverse dip to the former being 150

[1] *Paysage morainique*, p. 72.

[2] The deposition of the rich alluvia which cover the floor of the Po Valley, and to which it owes its wonderful fertility, began with the retreat of the glaciers when the rivers resumed their erosive energy, and continued throughout the long interglacial period after the maximum glaciation.

and to the latter 140 metres. The two last-named lakes afford, moreover, at their lower ends, typical examples of the formation of lake basins behind the terminal moraines of retreating glaciers, for in both cases the widened basins at the lower ends are appendages of the original fjords, and their contours conform strikingly to those of the concentric moraine walls behind which they were formed.

The zonal flexure also accounts for the extraordinary depth of the present lake basins as the result of overdeepening by the lowering of their floors, as against the theory of overdeepening by the direct action of glacial erosion, as if such steep, long, and narrow basins could be formed by the vertical scooping of a glacier in the same way as a cirque or corrie. The indirect action of the glaciers was more probably confined to the widening of the fjords and of the tributary valleys of the Dora Baltea, Ticino, Adda, and others.

The simultaneous operation of the zonal bending and the retreat of the glaciers on the one hand, and the recession of the sea from the Po Valley on the other, must have been of very long duration, probably till the end of the Ice Age, including the period of the last glaciation, which did not reach, and therefore did not directly affect, the contact zone of the sea and the moraine walls in the Po Valley.

Such extraordinary phenomena as the natural exit of the Como fjord being choked and its drainage reversed, so that the present lake has its only exit through the Lecco arm; or the former connexions between the Como and Lugano fjords at Menaggio and Porlezza, and through the Breggia Valley at Chiasso being severed by the lowering of fjord levels, and the Lugano fjord finding its exit through the Tresa into Lake Maggiore; or again, Lake Orta having its southern outlet barred and its drainage reversed to the north into the Toce; or, similarly, Lake Varese draining reversely into Lake Maggiore,—all these phenomena, as well as the labyrinth of erratic and tortuous watercourses throughout the morainic littoral and the whole lake district, are only some of the direct and indirect effects of that great maximum glaciation which has left its impress along the base of the Italian Alps both in Piémont and Lombardy by a morainic landscape in magnitude, grandeur, and variety unequalled in any other part of the Alps or of Europe.

V.—On the Evidence as to the Geological Structure of Cumberland bordering the Solway.

By T. V. Holmes, F.G.S., F.R.Anthrop.Inst.

(PLATE XIV.)

WHILE no doubts have existed among geologists that the rocks of this district are of Permo-Triassic age, that they are surrounded by older formations of the Carboniferous Series, and capped by a small Lias outlier, unanimity as to the relations of the local Permo-Triassic rocks to each other has never yet prevailed. Hence when the Geological Survey Memoir, by the present writer, on this district was published in 1899, Sir Archibald Geikie stated in the preface that the delay in its appearance was due to the hope that additional deep borings might have settled certain questions as to the relations to

each other of the rocks above the St. Bees Sandstone, etc. On this account, my own views (as those of the worker on the Geological Survey in this district) were allowed to be given by me in a paper read at the Geological Society in 1881, on "The Permian, Triassic, and Liassic Rocks of the Carlisle Basin" (Q.J.G.S., vol. xxxvii, May, 1881).

The difficulties preventing any thorough settlement of the question of the relations of the Triassic rocks overlying the St. Bees Sandstone to each other arise from the surface of North Cumberland being so much covered by Glacial Drift, alluvium, and other superficial beds. In the belt of ground near the boundary-line between the Permo-Triassic and Carboniferous formations the St. Bees Sandstone may be seen here and there in the banks of rivers, or in quarries, where the overlying drift is thin, though it is seldom wholly absent. But nearer the Solway, north of a straight line drawn from the coast between Maryport and Allonby to Carlisle, and west of the Eden, the surface is wholly covered by superficial beds of various kinds. And along the coast, from the spot just mentioned to Silloth, Bowness, and Carlisle, may be seen expanses of raised beach, blown sand, and other recent deposits, but no rocks of Permo-Triassic age appear except at Rockcliff, north of the Eden, and near its mouth. The Lias outlier, west of Carlisle, forms a plateau entirely veiled by Glacial Drift, so that the only sections showing Lias are very few and small, in the banks of tiny streams. Near Bowness, on the Solway, a boring showed the surface beds to consist of 41 feet of Glacial Drift. Southward, near Abbey Town, a boring showed the surface beds to be 12 ft. 6 in. of alluvial clay above 186 feet of Glacial Drift (Geol. Surv. Mem.).

The boring near Bowness was made in the year 1809; that near Abbey Town between November 14, 1875, and May 18, 1876. But for these two borings the existence of hundreds of feet of Gypseous Shales lying upon the St. Bees Sandstone, in this district west of Carlisle, would be unknown. In the Bowness boring were found (beneath the Glacial Drift) 367 feet of Gypseous Shales; and in the Abbey Town boring 734 ft. 6 in. of them above St. Bees Sandstone, in which the boring ended. Eastward of Bowness and Abbey Town, the late R. B. Brockbank, the discoverer of the Lias in Cumberland, kindly obtained for me a brief record of a boring at Orton, in the Lias area, made in the year 1781 (Mem., p. 22). This boring was for coal, the dark Lias shales having been mistaken for Coal-measures down to a much later date. At the surface were three fathoms of drift, then were found stones, "mostly bluish," and evidently Liassic, to a depth of 38 fathoms, and then "red stone or clay sometimes mixed with veins of white till they came to 60 fathoms". The evidence of the Bowness and Abbey Town borings thus decidedly suggests the presence of at least 22 fathoms of Gypseous Shales beneath the Lias at Orton, as the information obtained from the Orton boring.

East and north-east of Carlisle, in a country less invariably drift-covered than the district westward, is seen the soft, red, false-bedded Kirklinton Sandstone. It is best seen in the River Line, at and

north of Kirklinton, and is there the formation resting on the St. Bees Sandstone, though no clear sections appear at their junction. But in Carwinley Burn, which falls into the Esk north of Netherby, the line of junction of the St. Bees and Kirklinton Sandstones is clearly shown, and the unconformity between them unquestionable (Mem., p. 30). To the south-west of the above-mentioned places the Kirklinton Sandstone may be seen at Rockcliff and Cummersdale. But, west of the Eden, its boundary-line is hidden by the persistent nature of the drift covering the surface there, mentioned when treating of the Gypseous Shales. In the Memoir I have suggested that probably the boundary of the Kirklinton Sandstone under the Lias plateau may be the prolongation of a certain line of fault westward. Anyhow, the evidence of the old Orton boring seems to indicate the presence of at least 132 feet of Gypseous Shales there beneath 210 feet of Lias. It seems highly probable that the Kirklinton Sandstone, whether bounded, west of Carlisle, by a fault or not, does not extend beneath the Lias outlier so far westward as Great Orton.

Above the Kirklinton Sandstone, north of Carlisle, are seen the Stanwix Shales, which are mainly red and greenish-grey in colour. They are surrounded on all sides by the Kirklinton Sandstone, the junction between the two formations being well shown at Westlinton and near Cliff Bridge, Kirklinton. The Stanwix Shales may be seen also near Stanwix, north of Carlisle. At Carlisle the evidence from various sections is that "they rise gently southward between Etterby Scaur and Carlisle, and rapidly thin away to nothing at and west of that city". Also that "South of Beaumont there is no evidence as to the exact spot at which the Stanwix Shales abut against the Lias" (Mem., p. 35).

The Lias outlier, though covered by drift, forms a plateau having a boundary-line which, though somewhat vague in consequence of being veiled by its comparatively thin drift covering, yet is everywhere more or less distinctly noticeable. Hence there is a means of approximately ascertaining the boundary of the Lias which does not exist in the case of older formations, west of Carlisle, where the ground is not only more thickly drift-covered but the surface features consist of ridges of Glacial Drift, alluvial flats or peat-mosses.

We have now to consider the evidence bearing upon the comparative ages of the two formations resting upon the St. Bees Sandstone. These are the Gypseous Shales of the Bowness and Abbey Town borings, west of Carlisle, and the Kirklinton Sandstone north-east of the area occupied by the Gypseous Shales. For, as we have seen, there are no sections and no deep borings to settle the question. It always seemed to me that in all probability the Gypseous Shales were the older formation, as their thickness at Abbey Town and Bowness suggested that they occupied an area not only broader than that covered by the Kirklinton Sandstone but one attaining a much greater depth. And while the Gypseous Shales must have been deposited in a lake or lagoon, sandstone would be formed in a shallow and variable area. Then the junction of the

St. Bees and Kirklinton Sandstones in Carwinley Burn (Mem., p. 30) showed the Kirklinton Sandstone to be resting unconformably on that of St. Bees; while the narrow belt of country occupied by the St. Bees Sandstone, at the north-eastern end of the Carlisle Basin, between Carwinley Burn and the River Line, contrasts so strongly with the much broader areas occupied by it around Wetheral and Brampton as to suggest a very decided unconformity between the two sandstones.

In short, the Kirklinton Sandstone seemed to me (like the still narrower and thinner Stanwix Shales overlying it) to be in all probability confined to the north-eastern end of the Carlisle Basin, while the Gypseous Shales occupied a much wider space. And having been formed in a lake basin, and not in a shallow and irregular area, were much more likely to be an older formation than the Kirklinton Sandstone resting unconformably on that of St. Bees.

Since the publication of the Geological Survey Memoir I have not heard of any additional deep borings near Carlisle or in North Cumberland. But when "The Structure of the Carlisle–Solway Basin and the Sequence of the Permian and Triassic Rocks", by Professor J. W. Gregory, was discussed by the Geological Society, April 29, 1914, Mr. G. W. Lamplugh pointed out that "the westward prolongation of the Triassic basin of Cumberland had been proved in several borings in the north of the Isle of Man". He added that he had examined the cores of these borings, and that "they indicated the presence of at least 700 or 800 feet of gypsiferous and saliferous Keuper marl resting upon the St. Bees Sandstone, some hundreds of feet thick, below which there was a thin and inconstant series of Permian marl and sandstone with Brockram" (Abstracts of Proc. Geol. Soc., May 7, 1914).

The above evidence of Mr. Lamplugh is evidently most valuable in favour of the view that the Gypseous Shales of the Abbey Town and Bowness borings should rank as the formation immediately above the St. Bees Sandstone. On the other hand, the Kirklinton Sandstone, which rests unconformably on the St. Bees Sandstone in the north-eastern corner of the Carlisle Basin, and the Stanwix Shales overlying it, are formations confined to that district, and simply illustrate the local irregularities of the Permo-Triassic rocks. The resting of the Lias outlier partly on the Gypseous Shales, and partly on the Kirklinton Sandstone and on the Stanwix Shales, where the two formations last-named are thinning away to nothing, is surely nothing startling to our notions of the possible in the matter of this local position of the Lias. For with rocks like the Triassic, formed in areas so varied in their space and nature as those of Cumberland and the Solway especially are, we should surely be prepared to meet with local irregularities of this kind. For instance, in the discussion on Professor Gregory's paper at the Geological Society's meeting last year, Professor O. T. Jones remarked that in parts of South Wales "the Lias rested upon Carboniferous Limestone, but that was after the various subdivisions of the Trias had been overlapped in succession".

We may now turn from the beds overlying the St. Bees Sandstone to that rock itself and to the Permo-Triassic formations underlying it. They extend not only around Carlisle but up the Eden Valley as far as Kirkby Stephen, and are seen on the coast of Cumberland and Westmorland from St. Bees Head southwards. But those on the coast do not here concern me, nor do the beds of the Eden Valley demand more than the briefest mention.

In the Eden Valley district, for some miles from Wreay southward, there are three formations in the following order:—

St. Bees Sandstone.
Gypseous Shales.
Penrith Sandstone.

But north of Wreay and Cumwhitton, south-east of Carlisle, lines of fault cut off these Gypseous Shales with the underlying Penrith Sandstone, while the St. Bees Sandstone overlaps them and is the only one of the three formations to be seen north of these lines of fault in Cumberland. North of the Solway St. Bees Sandstone appears, near the shore, as far west as Annan. West of Annan may be seen Lower Carboniferous rock. And from Caerlaverock Castle, up Nithsdale, is another Permo-Triassic district, the conspicuous rock between Caerlaverock Castle and the town of Dumfries much resembling the Penrith Sandstone.

We have thus in the country bordering the Solway three districts of Permo-Triassic rocks—that of Nithsdale on the north-west, that of the Eden Valley on the south-east, and the Carlisle Basin in the centre. The last-named, extending, as we now know it does, from the information given by Mr. Lamplugh as to the deep borings in the Isle of Man, evidently occupies much the broadest area.

We are here concerned only with the Carlisle Basin. The lowest of the Permo-Triassic rocks forming this Basin is the St. Bees Sandstone, though possibly very deep borings might reveal the existence of fragments of still older Permo-Triassic rocks beneath it, here and there, as in the north of the Isle of Man. North of the junction with the Eden Valley series, near Wreay, the St. Bees Sandstone is the oldest Permo-Triassic rock visible in Cumberland. From Maryport to a point south of Wigton it rests on Coal-measures, and thence to Wreay on Lower Carboniferous rocks. Then the lines of fault already mentioned separate it from the Permo-Triassic rocks of the Eden Valley, and eastward and northward it rests upon Lower Carboniferous beds, both on the Cumberland side of the Border and north of the Solway as far west as Annan. From Annan towards the south-west it is beneath the level of the sea. Its dip between Maryport and the Caldew usually varies from north to north-west. Between the Caldew and the Hether Burn it slowly changes, being about south-west at the latter stream. North of the Solway it becomes more or less east of south. West of the Esk and at Annan it is nearly due south.

It has always appeared to me that (as just stated) the St. Bees Sandstone is the lowest Permo-Triassic formation forming the Solway Basin, though it is possible that (as in the Isle of Man) a thin and

inconsistent series of fragments might be detected here and there, by deep borings, of still older Permo-Triassic beds than the St. Bees Sandstone. In the opinion, however, of Professor Gregory (both as expressed at the meeting of the Geological Society on April 29, 1914, and in the GEOLOGICAL MAGAZINE for June, 1915, in his paper on "The Solway Basin and its Permo-Triassic Sequence"), the Solway Basin should be treated as being practically non-existent. In the GEOLOGICAL MAGAZINE he remarks that it "cannot have such a simple synclinal structure, for Carboniferous rocks occur at the surface near the northern shore of the Eastern Solway". Then follow interesting details of a boring for coal at Redkirk, all the rocks pierced being Carboniferous. And he considers the outcrop of Carboniferous rocks at Redkirk "opposed to the synclinal theory of the Solway", and adds that the existence of the St. Bees Sandstone in North-Western Cumberland "deep below a thick sheet of Gypseous Shales, rests on slender grounds which appear untenable". Having been over the whole district, and having traversed not only the roads but a very large number of the fields, and examined the banks of the various streams, I must reply that there is certainly sufficient evidence as to the existence of the St. Bees Sandstone where it is shown on the geological map. And that the deep borings showing the Gypseous Shales above it in Cumberland have now the additional support of the evidence of Mr. Lamplugh as to the deep borings in the north of the Isle of Man, which also show Gypseous Shales above St. Bees Sandstone. The result of deep borings since I was at work in Cumberland has therefore been simply to show the much greater range of the Carlisle Basin, and its greater importance as a geological feature of the Permo-Triassic rocks there than I had anticipated.

Then Professor Gregory is very doubtful as to the identification of the sandstone in the Abbey Town boring, beneath the Gypseous Shales, as the St. Bees Sandstone, and thinks it was in all probability Penrith Sandstone. He notes, in connexion with this view, that though I wrote on this district for the Geological Society in 1881 and for the Geologists' Association in 1889, my first mention of having seen the Abbey Town boring cores is in the Geological Survey Memoir of 1899. I was not aware of this omission till Professor Gregory noted it. But in the papers mentioned it did not occur to me to mention boring cores, simply because my knowledge of the geology of the district and, I may add, that of my colleagues, J. G. Goodchild, of the Eden Valley district, and R. Russell, of St. Bees and Whitehaven, made the existence of the St. Bees Sandstone somewhere beneath the surface at Abbey Town almost an absolute certainty. The boring originated in a local belief that coal would be met with there at a very moderate depth. Neither R. Russell nor I were consulted before the Gypseous Shales were pierced through, and then the appearance of sandstone, not coal, caused us to be asked to examine the cores showing the beds from a depth of 945 feet to 1,020 feet. We came to the conclusion that the lowest bed, 32 feet thick, was "St. Bees Sandstone of the ordinary type" (Mem., p. 20). It seems worth adding that we came to the conclusion that "the greystone of the Caldew river-cliff appears to be represented in the boring by the

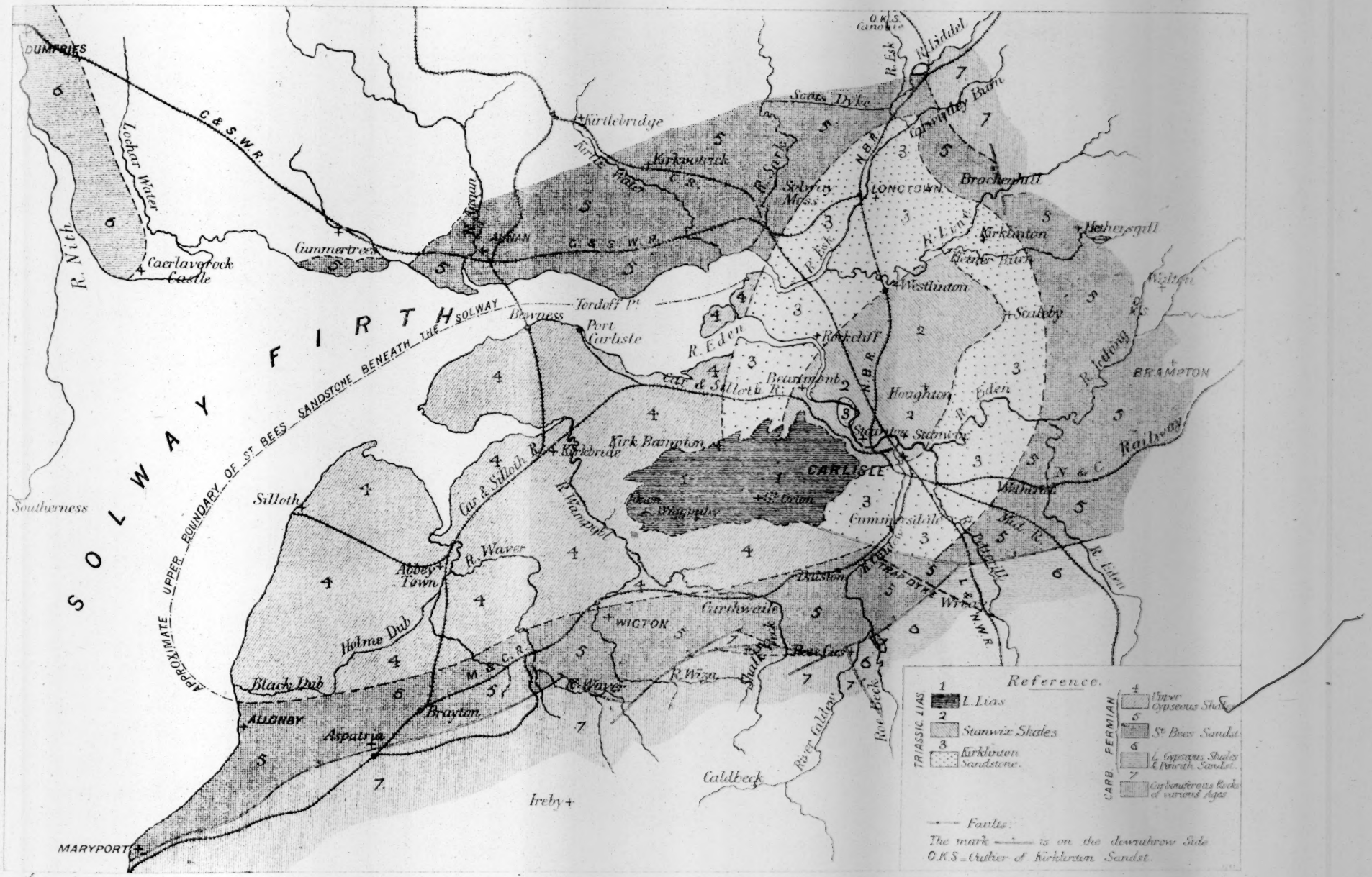
grey sandstone and shale directly overlying the red rock in which the boring ends". Also that this view is somewhat confirmed by the opinion of my colleague, J. G. Goodchild, then working in the Eden Valley district. "He (Goodchild) also thinks that the beds between Bracken How and this spot (Abbey Town) are higher than any he has seen in the St. Bees Sandstone of the Eden Valley district where the top beds are cut off by the great Pennine fault" (Geol. Surv. Mem., p. 20).

Bracken How is a house on the River Caldew. On descending this stream St. Bees Sandstone first becomes visible about 500 yards south of the house, and appears thence, at intervals, as far as the house itself (Mem., p. 18).

It may be well to state that any classification of mine, at any time, of these rocks as Permian, Triassic, Bunter, or Keuper has been simply to mark their *relative* positions locally; and that any changes of name have been simply in deference of the classifications of writers with a wider knowledge of Permo-Triassic districts. For though the Permo-Triassic rocks of Cheshire or the Vale of York are not likely to be identified with special formations in Nithsdale, the Vale of Eden, or the Carlisle Basin, yet a broad knowledge of the various localities must be the safest guide to such general classification as may be possible.

Professor Gregory notes that "the Dumfriesshire continuation of the St. Bees Sandstone rests unconformably on the Carboniferous without any Permian beds intervening". He then proceeds to speculate as to what lines of fault, etc., might have produced this state of things, which he seems to consider so strange and abnormal as to require some very special explanation. He has also misunderstood the nature of the difference between my view and that of some older geological surveyors as to the probable sequence of the formations of the Carlisle Basin. They (as already stated) thought that the Kirklinton Sandstone was an older formation than the Gypseous Shales resting on the St. Bees Sandstone in the Abbey Town boring. And that these Gypseous Shales probably belonged "to the same subdivision as the Stanwix Shales" (preface to Geol. Surv. Memoir). For then the Lias would rest conformably upon these representatives of the Keuper Marls in Cumberland. My own view was that the Gypseous Shales were older than the Kirklinton Sandstone. These differing views were simply with regard to the relative positions of the Gypseous Shales and Kirklinton Sandstone, and had no bearing on anything but the position of the overlying Lias. There were no doubts as to the truth of my views with regard to the position of the St. Bees Sandstone: that it rested on Carboniferous rocks of various ages (except above Wreay in the Eden Valley) and was the oldest of the Permo-Triassic formations of the Carlisle Basin.

While the persistent drift covering the country west of Carlisle made the relations of the Gypseous Shales and Kirklinton Sandstone to each other doubtful, the St. Bees Sandstone occupies an area in which rivers, streams, and quarries show a considerable number of sections, both north and south of the Solway. Hence the position of



SKETCH-MAP SHOWING THE ROCKS OF THE CARLISLE BASIN

(Disregarding Superficial Beds.)

Scale 1 2 3 4 Miles

Reproduced by permission from Quart. Journ. Geol. Soc. Vol. XXXVII. Pl. XI. 1881.

the St. Bees Sandstone immediately above Carboniferous rocks of various ages has given rise to no differences of opinion among geological surveyors. Nor have any of them felt that there was any need of a special explanation of the structure of the district involving the existence of hitherto unsuspected faults, etc. And in cases of this kind the Geological Survey, in its knowledge of local developments, irregularities, and local peculiarities of Permo-Triassic rocks, has necessarily a great advantage over any individual geologist.

Professor Gregory thinks that the absence of older Permo-Triassic rocks between the St. Bees Sandstone and Lower Carboniferous rocks in this district demands the arrangement of a series of faults, etc., to account for it. And that the presence of a thick bed of Gypseous Shales *above* the St. Bees Sandstone (as demonstrated by the Abbey Town boring) when there is one in the Eden Valley district *below* the St. Bees Sandstone, is so nearly incredible as to make it almost certain that the supposed St. Bees Sandstone in the boring was really the Penrith Sandstone. But I have already mentioned that R. Russell and I examined the cores of the lowest beds of the boring and found them to be St. Bees Sandstone. In fact, the surprise to us was simply to learn the great thickness of the Gypseous Shales above it. And recognizing the St. Bees Sandstone as the oldest bed of the Carlisle Basin, the absence of St. Bees Sandstone beneath the Gypseous Shales, and the presence there of Penrith Sandstone, would have seemed to us almost impossible; and certainly a state of things only to be explained by some arrangement of faults, etc., of which there was no visible evidence.

In short, the existence of the St. Bees Sandstone as the lowest bed around the Carlisle Basin, and as resting mainly on Carboniferous rocks, is unquestionable, and the absence of older Permo-Triassic beds there between it and Carboniferous formations is simply a local state of things to be recognized, not one to attempt to explain away as though it were necessarily an illusion.

Similarly, as regards the presence of Gypseous Shales both above and below the St. Bees Sandstone. There is no inherent probability in favour of either one or two. All the geologist has to do is to ascertain which way the evidence points, and to decide accordingly. In a district with Permo-Triassic areas like those near the Solway much more local irregularity must be expected than in the Vale of York or in Cheshire. Hence, at the Geological Society's discussion last year on the geology of the Solway district, after Professor Gregory's paper had been read, Dr. A. Strahan, the author of many Geological Survey memoirs, including one on the neighbourhood of Chester, showed no feeling of the impossibility of believing that the St. Bees Sandstone could lie upon Carboniferous beds, but stated that it "rested upon Carboniferous rocks along its margin both on the Scottish and on the English sides of the Border".

Then, as regards the presence here and there of Carboniferous inliers in the St. Bees Sandstone, they have long been known to exist at Hethersgill, in Shalk Beck, and in the Roebeck. Hence the presence of that at Red Kirk, mentioned by Professor Gregory, points to no new conclusion, though interesting as a detail.

In conclusion, I would remark that the most valuable addition to our knowledge of the geology of the Carlisle Basin made since 1881 is that of Mr. Lamplugh. I refer to his statement at the meeting of the Geological Society on April 29, 1914—which I have already mentioned—that deep borings in the north of the Isle of Man showed the existence there of 700 or 800 feet of Gypseous Shales resting upon St. Bees Sandstone. These deep borings very decidedly suggest the prolongation of the Carlisle Basin to the north of the Isle of Man. And they also tend to remove any scepticism as to the possibility of the existence of Gypseous Shales *above* the St. Bees Sandstone in Cumberland as well as below it.

VI.—The Ice Age in England.

By Dr. Nils Olof Holst (late of the Geological Survey of Sweden).

ENGLAND has only had one Glacial Period. G. W. Lamplugh pointed this out in 1906 before the British Association at York, and quite lately also in 1913 before the International Geological Congress in Canada.[1] No one has yet attempted to contradict it.

It is true that more than ten years ago, in the third edition of *The Great Ice Age*,[2] James Geikie put forward his theory that there were no fewer than six different glacial epochs. But of these the two last are only post-glacial climatic changes of minor importance, and may therefore be left out of consideration here. The remaining four have all, significantly enough, received foreign names: Scanian, Saxonian, Polandian, and Mecklenburgian, and are based very little on British but mainly on Swedish and German observations. None the less, they are of so much importance to the geology of Britain that a brief examination of them may not be out of place here.

As regards the oldest of these, derived from Scania, the southernmost part of Sweden, it may be said without the least hesitation that it depends on a complete misapprehension.

As is quite natural, when the Scandinavian inland ice first began to move to the south it advanced with considerably greater rapidity over the level Baltic Basin than it did over the mountainous highlands of Sweden. By the former road, therefore, it arrived more quickly in Southern Sweden, and here, still following the line of the Baltic Basin, there arose a direction of striæ markedly at variance with that which characterizes the main track of the inland ice during its principal phase. It is just on this fact that the Scanian glacial epoch was based. Meanwhile it has been shown that during its last stage no less than during its first the inland ice moved more readily in the Baltic Basin, and that consequently it continued to move there longer than on the mainland, maintaining the same divergence in the direction of its striæ as during the first stage, and finally that the last stage was *in full continuity* with the main phase.[3] The grounds for a Scanian epoch have thus been entirely cut away.

[1] G. W. Lamplugh, 1914. "The Interglacial Problem in the British Islands": C.R. Congr. Geol. Internat. Canada, 1913, pp. 427–34.

[2] London, 1894, pp. 608–12. Cf. Journ. Geol. Chicago, vol. 3, pp. 246–52.

[3] J. C. Moberg & N. O. Holst, 1899. *De sydskånska rullstensåsarnes vittnesbörd i frågan om istidens kontinuitet.* Lund.

In no circumstances, however, could there be any question of ascribing to the oldest striæ in Scania an earlier age than Cromerian. In this province there has now been found an analogue of the Cromer River, the so-called Alnarps River,[1] and there is not the least doubt that this is distinctly older than any of the Scanian moraines or striæ.

Geikie's fourth glacial epoch, Mecklenburgian, also called "Epoch of the great Baltic Glacier", in spite of its first German name may also be called Swedish in so far as its establishment was prompted by G. De Geer's paper "On the Second Extension of the Scandinavian Land-ice", published in 1884.[2] The maps of this extension drawn up by Geikie and De Geer are almost completely identical. Concerning this proposal of 1884, it may be enough to say that eventually, ten years later, De Geer so completely gave it up as to express the wish that his view of 1884 might be considered merely as a "working hypothesis" needed for that date.[3] He was forced to this admission by Ussing, who was able to show that the inland ice of Denmark had never such an extension as was given to it by De Geer.[4]

There remain Geikie's two purely German glacial epochs; but it seems right and fitting to let the Germans themselves reply for them.

At the International Geological Congress in Canada W. Wolff, who, as a Prussian geological surveyor and in particular a Quaternary geologist of many years experience, knows the North German Drift as well as anyone else, subjected the 'glaciations' of Northern Germany to a critical but, as it seems to me, a somewhat too favourable examination.[5]

There "may be question", he says, "of three such, but in no circumstances of four." The first great difficulty met with is that no geologist can even yet fix the extreme limit for more than the middle one—the greatest glaciation. As regards the first, this may be explained by the fact that its traces are completely covered by those of the second or middle glaciation; but this explanation cannot apply to the third or last glaciation, the southern limit of which is supposed to lie somewhere between the Baltic and the Elbe, or perhaps south of the Elbe, without anybody precisely knowing where it really is.

Wolff admits, as he is bound to do, that it is only the interglacial deposits which can be adduced as proof for the separate glaciations. But no such persistent deposit traceable over the whole or the greater part of North Germany has ever yet been proved. The interglacial deposits are more or less local or sporadic, but such as they are they appear in considerable numbers and constitute the most confused

[1] N. O. Holst, 1911. "Alnarpsfloden, en Svensk 'Cromerflod'": Sveriges geol. Undersök., ser. C, No. 237.

[2] Gerard De Geer, 1884. "Om den skandinaviska landisens andra utbredning": Geol. Fören. Stockholm Förh., Bd. 7, p. 436. Also, 1885, Zeitschr. Deutsch. Geol. Ges., Bd. 37, p. 177.

[3] Feb. 4, 1904. Geol. Fören. Stockholm Förh., Bd. 26, p. 92.

[4] N. V. Ussing, 1903-4. "Om Jyllands Hedesletter og Teorierne for deres Dannelse": Oversigt Danske Videnskab. Selsk. Förh., 1903, pp. 99-152. Résumé en français, pp. 153-65.

[5] W. Wolff, 1914. "Ueber Glazial und Interglazial in Norddeutschland": C.R. Congr. Geol. Internat. Canada, 1913, pp. 467-77.

mixture of salt- and fresh-water deposits, peat and beds of multifarious composition, deposits more or less covered by moraine or frequently covered only by sand, and so forth. And Wolff might have added that from time to time the various deposits now known to be either pre-glacial or locally post-glacial have been made to serve as good proofs of an interglacial epoch. This production of proof has undergone a continuous and regular development: year after year the old proofs once thought so satisfactory have been found wanting and cast aside to make room for newer and better ones.

As "the most certain of all the North German interglacial deposits" is at present regarded the *Paludina* bed, which in Berlin and its environs has been shown to lie between two moraines interpreted as having been deposited during the first and the second glaciations. But this has not always been the case. F. Wahnschaffe, for many years the leading interglacialist of North Germany, expressed himself as follows about the *Paludina* beds in 1893[1]: "*Paludina diluviana* had its home in the North German lowlands, before the lower moraine was deposited there, since the large accumulations of shells of both adult and young individuals as well as the condition in which the shells were preserved left no doubt but that the molluscs in the *Paludina* beds of Berlin occurred *in situ* ('auf primärer Lagerstätte'). On the other hand, in the moraine it is a derived fossil, and then it was driven for ever ('dauernd') from its old home." Subsequently, in 1901, the same geologist transferred the *Paludina* bed from pre-glacial to interglacial deposits, with the absurd consequence that there were no longer any pre-glacial deposits in the whole of the North German lowlands. "The existence of pre-glacial formations," says Wahnschaffe, "is not yet proved, inasmuch as the fossiliferous deposits formerly regarded as pre-glacial are now referred to Interglacial I."[2] But, as is well known, this warmth-loving snail has now withdrawn itself to the lower Danube, to the neighbourhood of the Black Sea. Moreover, it occurs fossil in North Germany together with admittedly pre-glacial Mollusca, and in England it is admittedly pre-glacial, since it there occurs only in the older pre-glacial deposits: in the *Neritina* locality at Swanscombe as well as that at Clacton-on-Sea. Thus the appearance of the mollusc in England is quite clearly decisive for Wahnschaffe's earlier view, and the first two North German glaciations are changed to a single one. Moreover, Wolff himself in another connexion explains that the oldest glaciation is very problematic ("dem ältesten Glazial haftet viel Problematisches zu").

Finally, as regards the "younger interglacial formations", which should distinguish the second and third glaciations, Wolff points out as an indisputable fact that, in consequence of their manifold forms and their position on so many different horizons, they cannot be regarded as contemporaneous. They are usually covered only by sand and gravel, no bottom moraine has gone over them, etc. He

[1] F. Wahnschaffe, 1893. "Ergebnisse einer Tiefbohrung in Niederschönweide bei Berlin": Zeitschr. Deutsch. Geol. Ges., Bd. 45, pp. 292–3.

[2] F. Wahnschaffe, 1901. *Die Ursachen der Oberflächengestaltung des norddeutschen Flachlandes*, 2 Aufl., p. 239, Stuttgart.

therefore regards them as due to many different oscillations of the inland ice. That is as much as to say that it is quite incorrect to imagine here two different glacial epochs, and indeed not quite correct to speak of two different 'glaciations'.

What we have here before us is nothing else than *the first great melting stage of the inland ice.* The limit of this in space lies between the periphery of the glaciated region and the 'circumbaltic' terminal moraine which can be followed through the whole of North Germany far into Poland, and on the other side up through the east part of Holstein and Schleswig into Jutland, where it curves round to the west and finally for about 56° 30′ of longitude turns directly westward towards England, as though it would continue its course there.[1] In time this melting stage must be ascribed to a period of milder climate well known to archæologists as characterizing the Aurignacian and Solutrian stages, a view elaborated in a previous publication.[2]

This melting stage can also be observed in England, and to some extent its limits can be traced there too, but this will be better discussed on a subsequent page. The only point to be emphasized here is that the correspondence between England and North Germany is so complete that even the latter country has no better claim to more than one ice age. In Belgium there is no trace of more than one, and in Holland likewise was only one, there called 'die Haupteiszeit'. In the last-mentioned country, however, geologists are at present uncertain whether it should be ascribed to the 'Riss' or to the 'Mindel' period, on the supposition, that is, that there really was more than one period. But it would seem that the problem of nomenclature might well be postponed until it has been proved that there really was in Northern Europe anything corresponding to the Alpine epochs of Penck. Penck, indeed, has never committed himself to this view, but has, on the contrary, expressly explained that he "holds the view that the classification of the Alpine glacial deposits cannot be transferred to North Germany without further evidence".[3]

Before the attempt is made in the following pages to draw the limits of the Ice Age in England and to assign it to its proper position, it seems fitting to say something about the pre-glacial conditions, which may be regarded as having in all probability had some connexion with the appearance of the Ice Age.

[1] Ussing, op. cit., 1903, see map.

[2] N. O. Holst, 1913. "Le commencement et la fin de la période glaciaire": L'Anthropologie, tome 24, p. 377.

[3] 1912. C.R. Congr. Geol. Internat. Stockholm, 1910, p. 1076.

To correlate the phenomena of the Ice Age within this little Alpine district with those in the great glacial district of Northern Europe constitutes undoubtedly no easy problem, and we cannot blame Penck if he delays to express himself upon it. "The master is still in his workshop, and has not yet finished his work." No one can wish to urge him on with indecent haste, but it would certainly be most illuminating if he would let us see what he already has finished. For one thing it might put a check upon his pupils, so that they should not in their enthusiasm press too far, and further than he himself wishes.

K. A. von Zittel has remarked that between the typical mammalian fauna of the Pliocene age, as found in the Val d'Arno, in Auvergne, and in the Montpellier district, and that which characterizes the older Pleistocene, there is intercalated a passage fauna, which for the most part agrees with the latter, but contains besides the following five species, namely, *Elephas meridionalis*, *Rhinoceros etruscus*, *Ursus arvernensis*, and the two species of *Cervus*, *C. Sedgwicki* and *C. verticornis*. Among places where this passage fauna is to be found is mentioned especially the Cromer Forest Bed, but also the French localities Saint Prest, Chagny, and Durfort, as well as some Italian localities. Here, then, appears to be a new division of time, as is maintained also by W. Boyd Dawkins, when he characterizes the Cromer Forest Bed as the period "when the Mammalia were migrating from Northern Asia" (and he might have added "and from Northern Africa") "into Europe in the pre-glacial or early stage of the Pleistocene period".[1]

The immigration into Europe of this late Pliocene or older Pleistocene mammalian fauna corresponds, as Von Zittel remarks, to a similar migration from North into South America and from South into North America.

In particular reference to the immigrating European fauna, he remarks that it required "together with a more temperate climate" also "an abundant vegetation", which in its turn must have required an abundant rainfall. During the preceding Pliocene times conditions had been otherwise. Then "large freshwater lakes were absent", that is to say, the rainfall was then less abundant.[2] This finds confirmation also in England, where the land and freshwater molluscs of the Pliocene are not known from freshwater deposits, but from the marine deposits of the Crag in which they have been embedded.

If Von Zittel's limitation of Pliocene time be retained, it may be definitely stated that it was towards its close that Europe became subjected to pluvial conditions, inducing a richer vegetation, which attracted the large and small herbivorous mammals; and that they in their turn attracted the large and small carnivores, as well as man, who, in a certain sense, may be regarded as the largest carnivore, since he lived on all the other animals. Thus man's contemporaneous appearance in Europe receives its full explanation.

The question of man's first appearance at the beginning of the pluvial epoch receives further elucidation from the following facts.

The English Cromer River must not be considered as an isolated example. There was also in the South of Sweden a very large, approximately contemporaneous river, the so-called Alnarpsfloden, which ran down from East Prussia over the southernmost part of Sweden, and then up to the "Norwegian trough". The oldest and deepest river-deposits in the valleys of the Elbe and Weser also appear to be approximately contemporaneous. All these rivers

[1] W. Boyd Dawkins, 1903. "On the discovery of an Ossiferous Cavern of Pliocene Age at Doveholes, Buxton (Derbyshire)": Quart. Journ. Geol. Soc., vol. 59, pp. 105–32. See p. 122.

[2] K. A. von Zittel, 1895. *Grundzüge der Palaeontologie*. See pp. 946, 947, 944.

resemble one another in that they flowed when the whole of Northern Europe lay considerably higher than at present.[1]

As regards such comparatively small rivers as the Thames, the Frome, and the Avon, the period of their strongest erosion certainly seems to have been somewhat later (Abstr. Proc. Geol. Soc., 1915, No. 972, pp. 70–1; No. 974, p. 85). But this does not contradict the supposition that they may have begun their course somewhat earlier, perhaps indeed near to the period of the Cromer River.

Palæolithic implements are said, as is well known, to have been found in the deposits of the Cromer River. The finds that I have had the opportunity of examining seem, however, to have an Eolithic rather than a Palæolithic cast. True Palæolithic finds cannot, however, be said to be entirely unexpected, since if the human jaw from Mauer really is contemporaneous with the Mastodon fauna occurring there, then the deposits containing it are older than those of the Cromer River, and man might just as well have left traces of his existence in the later deposits as in the earlier one, provided that he appeared in England as early as he did on the Continent.

The cave-deposits bear the same witness as the river-deposits, but, being more accessible to investigation, they speak a clearer language. Cave-deposits were, as a rule, laid down by subterranean streams, which, however, as proved by fossils, did not begin to run before the close of Pliocene times. The caves, therefore, are Pleistocene. Dawkins has, it is true, described a cave of Pliocene age found at Doveholes in Derbyshire, and mentioned by him as "the only Pliocene cave yet discovered in Europe". But he himself states that the Pliocene animal remains were 'derived' ("conveyed from a higher level into it [the cavern] by water").[2] This cave, therefore, is younger than the bones preserved in it, and it too may very well be of Pleistocene age.

Kent's Cavern, the most thoroughly explored of the English bone-caves, obtained the first material for its oldest deposit—a breccia—from sand carried by a subterranean stream which flowed through it. In this breccia are found the oldest Palæolithic flint implements, the so-called Pre-Chellean, right down to the floor, and bones of the cave-bear are found only a couple of feet above the floor.[3] For the rest the breccia has up to the present only yielded the bones of the cave-lion and the fox, and these are only of sporadic occurrence.

Similar conditions are met with in Brixham Cave.[4] The lowest deposit, "the shingle bed," was, it is plain, likewise laid down by a subterranean stream. Certainly it is very poor both in flint implements and bones, but among the latter the bear is represented, and the underground brook cannot have begun to flow much before the entrance of the oldest Palæolithic mammalian fauna.

[1] Holst, op. cit., 1911, pp. 30–1, 61–2.

[2] W. Boyd Dawkins, op. cit., 1903, pp. 129 and 125.

[3] Sixteenth and concluding Report of the Committee appointed for the purpose of exploring Kent's Cavern, 1881. Rep. Brit. Assoc. for 1880, p. 68.

[4] J. Prestwich, 1874. "Report on the Exploration of Brixham Cave": Phil. Trans., vol. 163, p. 471.

In the Belgian caves the conditions are different in so far as man appears in them (with the exception of the Spy cave) at a distinctly later date, but they are similar as regards the oldest bone remains of the cave-lion and the cave-bear. In the lowest of the five layers in the Hastière cave, the cave-lion first appears as the oldest animal. The same condition obtained in the third cave at Goyet. Here the cave-bear is found immediately above the horizon with the cave-lion.

Many other bone-caves might be quoted in illustration, all leading to the same result; their first filling up, being in connexion with subterranean water arising from a more copious rainfall, was not older than, but probably just contemporaneous with, the immigration of a new Pleistocene mammalian fauna. As regards the cessation of the pluvial epoch, it may here be enough to mention that as a rule it terminated at the same time as the Ice Age, and therefore did not come to an end quite at the same time in the northern and southern regions. In the bone-caves it usually ceased with the uppermost stalagmite, "granular stalagmite," as is the case in Kent's Cavern.

Even more clearly than in Europe can the pluvial epoch be observed in Northern Africa from Egypt to Morocco. There a number of places on the borders of the desert region were inhabited during Palæolithic times by no inconsiderable population, but are now uninhabitable. The power and high civilization attained by Egypt in post-glacial times under the first pyramid-building dynasty is but the continuation of a long development strongly fostered by nature during the pre-dynastic glacial and pluvial epochs. It should perhaps be recalled here that the first Egyptian dynasty began to rule 5,230 (3315 B.C. + 1915 A.D.) years ago (according to E. Meyer) or 7,415 (5500 B.C. + 1915 A.D.) years ago (according to W. M. Flinders Petrie), while the close of the Ice Age in Southern Sweden, according to my calculation based upon archæological finds in the Swedish peat-bogs, may be regarded as having taken place about 7,000 years ago (at a maximum).[1]

A discussion of the very extensive question of the North African climate in Pleistocene times would, however, lead us too far, and I shall here confine myself to referring my readers to an archæological work by Professor L. Capitan and his colleagues, in which are to be found numerous elucidations of the changes of climate in Northern Africa from Palæolithic down to historic times,[2] as well as to a report on various cognate observations made by the Geological Survey of Egypt.[3]

[1] N. O. Holst, 1909. "Postglaciala tidsbestämmingar": Sveriges Geol. Undersök., ser. C, No. 216.

[2] J. de Morgan, Capitan, & P. Boudy, April, 1910. "Étude sur les stations préhistoriques du Sud Tunisien": Rev. École Anthrop. Paris, tome 20.

[3] W. F. Hume, 1910. "Climatic Changes in Egypt during Post-Glacial Times": pp. 421–4 of Die Veränderungen des Klimas. Sep. publ. Congr. Geol. Internat., Stockholm.

(*To be continued in our next Number.*)

NOTICES OF MEMOIRS.

Opalized Shells from New South Wales.

On some Molluscan Remains from the Opal Deposits (Upper Cretaceous) of New South Wales. By R. Bullen Newton, F.G.S. Proc. Malac. Soc. London, vol. xi, pt. iv, pp. 217–35, pl. vi, 1915.

THE famous opal deposits of New South Wales, first referred to in geological literature by M. W. Anderson in 1892 as of Upper Cretaceous age and the probable equivalent of the Desert Sandstone of Queensland, has yielded from time to time the remnants of an interesting fauna and flora in which original structures have been replaced by opaline matter of rich and varied coloration. Further writers on this subject include the names of J. B. Jaquet, G. de V. Gipps, R. Etheridge, jun., H. Woodward, Ralph Tate, G. Gürich, A. S. Woodward, and F. Chapman. Some new material from White Cliffs (N.S.W.) was recently obtained by Mr. Newton from a gem merchant in Sydney, during a visit last year to Australia to attend the meeting of the British Association, and he has made it the opportunity of preparing a small memoir upon the palæontology of the deposits with special reference to specimens in the British Museum (Geological and Mineral Departments) and in the private collection of the Rev. F. St. J. Thackeray, of Mapledurham. Including the new species described, the Pelecypoda now comprise seventeen forms or species, whereas only two species of Gastropoda and three Cephalopoda have as yet been recorded. The genus *Unio* is recognized for the first time from these beds, three new species being described, while two new species of *Cyrenopsis* are also added to the fauna. Associated with these and other fresh-water Mollusca are certain marine forms belonging to *Fissilunula*, *Inoceramus*, *Euspira*, *Actinocamax*, etc., which indicate an estuarine origin for the deposits. Mingled with these are fossils of other groups such as *Araucarioxylon*, *Isocrinus*, *Ceratodus*, *Cimoliosaurus*, *Polyptychodon*, and Dinosaurian remains. The author points out an interesting resemblance which he has traced between this fauna and that characterizing the uppermost Cretaceous beds of Canada, particularly the Belly River Series of Alberta, which is also of estuarine character, the inference being that the Australian opalized deposits were probably laid down in similar late Cretaceous times.

REVIEWS.

I.—C. Schuchert. Revision of Paleozoic Stelleroidea, with special reference to North American Asteroidea. United States National Museum, Bulletin 88, 302 pp., 38 plates. 1915.

THIS book is not what Professor Schuchert intended when he first began the work, but it will be most useful for all that. The most original part is the description of the older Palæozoic starfishes

of North America. The account of the later forms, of the ophiurids and their allies, and of the foreign material is mainly compilation, and that it is no more is due to change of circumstances since the work was begun. Still, an intelligent compilation may be valuable as a summary of our knowledge, and certainly it is a great convenience to have had the literature so thoroughly ransacked for us.

The rather barbarous name Stelleroidea, adopted from Gregory, is intended to comprise all those animals generally known as Asteroidea and Ophiuroidea, with a number of other forms evidently allied to them but apparently forming distinct lines of descent, and therefore not properly to be placed in either of those Classes. To cover the same conception Mr. W. K. Spencer has restricted the name Asterozoa, which originally had a still wider content.

We can trace within known geological time the broad lines of development that gave rise to the modern Ophiuroid type, but the other groups, it is clear, already coexisted in fairly definite forms at the earliest period from which we have any traces of Asterozoa at all. That period is the Middle Ordovician, but the abundance and diversity of starfish life then appearing make it quite clear that there must have been ancestors provided with skeletons capable of preservation. Before we can advance much further the fossils of those ancestors must be found. They will decide between several conflicting theories. Professor Schuchert is led by various considerations to regard his new genus *Hudsonaster* as the most primitive known form. Besides ambulacrals and adambulacrals this contains inframarginals, supramarginals, and a dorsal radial series, but it has no accessory plates. The structure is simple, that is obvious; but this simplicity may be the result of specialization from a less definitely constructed ancestor. Professor Schuchert, however, does not think so, but imagines an ancestor more simple still. It all sounds very logical, but one is left wondering what the creature did for a living. There is also a curious want of harmony with the facts of embryology as regards the terminals, and one can hardly believe that there was so striking a difference in this fundamental point between the earlier Asteroidea and their modern descendants. Even Professor Schuchert seems to have his doubts. I would also venture a doubt as to his comparison with Echinoidea; at any rate it is far from certain that "the ambulacrals" of Echinoidea are the "same ossicles as in Stelleroidea", or that the "interambulacrals = adambulacrals of Stelleroidea".

It is not possible here to enter into a critical examination of the systematic descriptions, but I must not leave to another the ungracious task of pointing out that the new species *Hudsonaster batheri* is based on the imprint of the apical face of *Tetraster wyville-thomsoni*. I told Professor Schuchert this many years ago when I sent him the squeeze for study, and my verdict is now endorsed by Mr. W. K. Spencer from his renewed examination of the original specimens.

Congratulations to Professor Schuchert on having at last got this laborious piece of work into the world.

F. A. Bather.

II.—Some Mineral Oil Regions.

1. Report on Petroleum in Papua. By Arthur Wade, D.Sc.—The author is to be congratulated on having brought to notice a part of the Empire in which the oil indications are certainly widespread, though it remains for actual drilling to test the real productiveness of the field. The oil indications are noted in a series of sandstones and mudstones of Middle Tertiary age, and are folded in a general north–south direction. These beds are partly overlain by a calcareous succession of Upper Tertiary age, which has east–west trend lines parallel to the coast. It appears probable that the east–west trend lines of Java extend into Papua, and in the latter country they begin to swing round into the north–south trend lines which the author describes; this inference appears to be confirmed by the inconstancy of the trend lines in certain areas.

The hypothesis that the minor crumpling of the anticlines is due to the falling in of the crests is interesting and important in its technical application to oil drilling, but it certainly demands more proof than has been given in the paper.

2. The Moorcroft Oil-field and the Big Muddy Dome, Wyoming. By V. H. Barnett. (Bull. 581 C, U.S. Geol. Surv.)—Both these areas are composed mainly of Cretaceous rocks, the Montana and Colorado groups being well developed. Doubtful Jurassic beds also occur, while in Big Muddy Dome, Tertiary sandstones and shales occur in small patches. The general lithology and structure are similar to those of neighbouring oil-fields along the eastern border of the Rocky Mountains, but the commercial prospects are distinctly poor. In the Moorcroft region, a poor oil-bearing sand is noted, but the structure is unfavourable for subterranean storage, whilst in Big Muddy Dome it is significant that the only horizon which the author claims may contain oil in the middle of the dome, i.e. the Wall Creek Sandstone, has nowhere along its outcrop been proved to contain any bituminous matter.

3. Oil- and Gas-fields in Wayne and McCreary Counties, Kentucky. By M. J. Munn. (Bull. 579, U.S. Geol. Surv.)—The structure of this region is that typical of Pennsylvanian oil-fields, consisting of gently undulating strata ranging in age from the Ordovician to the Carboniferous. The latter is represented by a good development of both the Pennsylvanian and Mississippian subdivisions with the usual unconformable relationship, the Mississippian consisting mainly of limestones and containing the oil-bearing strata. The Chattanooga Shale at the base of the Carboniferous is correlated with the Devonian, though the evidence is unsatisfactory. Below these shales is a marked break in the succession almost eliminating the whole of the Silurian, whilst the Ordovician are not exposed but are found in boreholes.

With regard to the distribution of the oil pools, it is remarkable that these appear to occur in the sides of the gentle synclinal sags. This peculiar distribution may be the result of unequal porosity in the oil-bearing bed, and also the result of gas pressure in a water-free horizon.

4. Oil and Gas in the Western Part of the Olympic Peninsula, State of Washington, U.S. By C. T. Lupton. (Bull. 581 B, U.S. Geol. Surv.)—The country examined is composed of a strongly folded suite of Cretaceous and Lower and Middle Tertiary rocks, almost wholly covered by Pleistocene deposits. The exposures are rare, being confined to sea-coast and rivers, and the country densely wooded. It is hardly surprising that the author's idea of the general stratigraphy and of the structure, after such a short visit, is hazy in the extreme, and the account degenerates into a painstaking but tedious catalogue of dips and strikes.

The fact that oil and gas certainly exist, and that this region lies in the same trend-line with the rich Californian field, indicates that the region is worthy of careful investigation.

5. Oil Shale of North-Western Colorado and North-Eastern Utah. By E. G. Woodruff and David T. Day. (Bull. 581 A, U.S. Geol. Surv.)—The oil-bearing shale forms a part of the Green River formation, and occurs as beds of variable thickness up to 80 feet and is of lenticular shape, the whole outcrop extending over 100 miles in length along a sinuous escarpment.

The authors' description of the shale proves that the latter differs materially from the usual oil shale of Scotland, in that the large proportion of the bituminous matter occurs as free oil impregnating the shale. It is very questionable whether the authors' claim that the results of their experimental retorting have a limit of error of merely 20 per cent is borne out by experience. Distillation with small experimental retorts never yields the same results as with modern commercial apparatus, and, merely by the introduction of steam into the distillation, the yield of oil can often be increased by 50 per cent.

Finally, the economic aspect of the problem is largely dependent on an important factor which the authors appear to have overlooked, i.e. the yield of ammonia, and it is a pity that more data on this important factor have not been given.

6. The supposed Oil-bearing Areas of South Australia. By Arthur Wade, D.Sc. (Bull. 4, Geol. Surv. S. Australia.)—The district examined forms the coastal regions near Spencer Gulf and Kangaroo Island. The country is floored by an interesting series of pre-Cambrian metamorphic rocks—with local patches of Cambrian and Permo-Carboniferous glacial beds, and a thin veneer of Tertiaries—not a very hopeful region for the oil prospector. The author proves that all the reported oil shows are based on misapprehensions, and a large portion of the paper is devoted to the disillusionment of the general public on certain deeply rooted fallacies regarding the occurrence of oil. For the rest the paper adds little to our knowledge of the general geology.

III.—Oligocene Mollusca from the Silex Beds of Florida.

DR. W. H. DALL has recently issued an exhaustive treatise on the *Molluscan Fauna of the Orthaulax pugnax zone of the Oligocene of Tampa, Florida*, which forms Bulletin 90 of the United States

National Museum, 1915, published by the Smithsonian Institution. Near Ballast Point in the neighbourhood of Tampa Bay, Florida, occur certain limestones associated with clays, marls, and cherts, which are very fossiliferous. The calcareous structures have disappeared through solution, so that the fossils are mostly represented by siliceous cavities the characters of which can be reproduced by wax or gutta-percha impressions, but where silicification has been more complete the organisms are preserved as beautiful translucent objects in silica besides being sometimes of various shades of brown. A number of silicified corals, also, accompany the shells of these deposits, as well as Foraminifera represented by *Orbitolites floridanus* of Conrad, a form closely related to Lamarck's *O. complanata* of the European Eocene. The author furnishes his monograph with an interesting review of the literature of the subject, commencing with the earliest notice of the beds written by John H. Allen in 1846 (Amer. Journ. Sci., ser. II, vol. i, pp. 38–42), followed by references to the researches of Conrad, J. W. Bailey, Heilprin, Dall, T. L. Casey, G. C. Matson and F. C. Clapp, Bailey Willis, and T. W. Vaughan. From the occurrence of the characteristic fossil, *Orthaulax pugnax*, in the Oligocene beds of Panama, Antigua, Anguilla, etc., the author considers that the Silex Beds of Tampa may be correlated with the Oligocene deposits of the West Indian and Caribbean regions. It is recognized that 312 species and varieties of Mollusca are now known from this zone, of which more than ninety are described on the present occasion as new; they bear the estuarine facies, being made up of land and freshwater species as well as marine forms. The whole of this fauna is systematically described and figured, the text occupying 173 pages, while the twenty-six plates of illustrations form a handsome addition to the work. The monograph, like all previous writings of the author, has been prepared with great thought and detail, many remarks being offered on conchological nomenclature which cannot fail to be of the utmost service to all students of molluscan science.

IV.—Brief Notices.

1. Human Remains and Implements in England.—In a recent number of *L'Anthropologie* (vol. xxvi, p. 1, 1915) Professor Marcellin Boule has published a paper entitled "La Paléontologie Humaine en Angleterre". In this he gives a critical account of recent papers dealing (1) with flint implements and (2) with human remains. The first part is concerned chiefly with the vexed question of the nature of the so-called rostro-carinate implements from the base of the Crag. The author, after carefully considering the various papers dealing with the subject, comes to the conclusion that these implements are of purely physical and natural origin and not the work of man at all. The second part of the paper discusses for the most part the already large number of papers relating to the Piltdown man. Professor Boule on the whole supports the views of Dr. Smith Woodward as against those of Professor Keith. At the same time, however, he seems inclined to accept the very improbable suggestion put forward by

several writers that the mandibular ramus may belong to a different animal from the skull, and he objects to the use of the generic name *Eoanthropus*. The age of the deposits in which the remains were found is considered to be early Pleistocene.

2. In the Annals of the South African Museum (vol. xii, pt. ii, 1915) Mr. S. H. Haughton publishes several papers on South African Reptiles and Amphibia. The first describes a very fine skull of *Trematosaurus*, referred to a new species, *T. sobeyi*: the sutures are well shown in the specimen, and a detailed account of the various elements is given. The other papers deal with a new Dinocephalian similar to *Mormosaurus*, two new Therocephalians, and some new Anomodonts. The number of new genera and species of South African reptiles described lately is extraordinary, but since the material is often very badly preserved it seems probable that many of the names are really synonymous.

3. On an Extinct Marsupial from the Fort Union, with Notes on the Myrmecobidæ and other Families of this Group. By J. W. Gidley. (Proc. U.S. National Museum, vol. xlviii, p. 395, 1915.)—In this paper the author describes the occurrence in the Palæocene beds of Fort Union of a small Marsupial which he considers to be nearly related to *Myrmecobius*, hitherto the sole representative of a family found only in Australia. The new form, to which the name *Myrmecoboides montanensis* has been given, is, at present, known only from the ramus of a mandible, so that its affinities cannot perhaps be regarded as definitely settled, but the similarity of the dentition to that of *Myrmecobius* is very striking. If this relationship is confirmed the origin of some at least of the Marsupial families is carried much further back than was suspected, and it would appear that some of the Australian types were already differentiated before they became restricted to that continent.

4. Southern Rhodesia: Report of the Director, Geological Survey, for the year 1914. Fol.; pp. 8. 1915.—The Director (Mr. H. B. Maufe) explains that two new districts have been investigated during the period of 1914, which include the examination of the Kimberlite 'fissures' and 'pipes' in the Bembesi and Shangani basins and the mapping of the diamondiferous Somabula Series, together with the mapping of the Forest Sandstone and basalt country around Shiloh, situated to the north of Bulawayo. Reptilian remains were found when sinking a well in the Forest Sandstone at Waterfall Farm, which Mr. S. H. Haughton regards as belonging to a new species of Dinosaur whose nearest South African allies are of Upper Karroo age. It is therefore considered that the Forest Sandstone, which has hitherto not been satisfactorily placed in the geological series, should now be correlated with some member of the Upper Karroo System.

5. Geological Survey of Western Australia.—Bulletin No. 62 of this Survey, published 1914, contains "Notes on the Geology and Mining at Sandstone and Hancock's, East Murchison Goldfield", by E. de C. Clarke, with interpolated remarks on the 'Petrology' of the region by R. A. Farquharson. From a prefatory note of the

Government Geologist, Mr. A. Gibb Maitland, we gather that the most important structural and topographical features of Sandstone are the so-called 'jasper bars' which traverse the field in a general east and west direction. They pass imperceptibly into graphite schists below the ground, and from microscopical examination have evidently suffered intense shearing, being in places represented by chlorite-schists. Including the index, this work comprises sixty-six pages of text, maps, plans, etc., together with occasional micro-photographs exhibiting rock structures.

6.—Geological Survey of Ireland.

Explanatory Memoir to Sheet 58, illustrating parts of the Counties of Armagh, Fermanagh, and Monaghan. Second edition. By T. Hallissy; with Petrographic Notes by G. A. J. Cole. Department of Agriculture and Technical Instruction for Ireland, 1914. pp. i–iv, 1–26, with a coloured geological map, scale 10 miles to $3\frac{3}{4}$ inches. Price $3\frac{1}{2}d$.

The sedimentary rocks of this region are recognized as Ordovician (Lower Silurian), which include the Llandilo and Caradoc Beds; Gotlandian (Upper Silurian), Llandovery Beds; Carboniferous, embracing Lower Limestone, Calp or Middle Limestone, Upper Limestone, and Yoredale Series; Post-Pliocene and Recent, including Glacial Drift, Peat, and Alluvium. Ample notes are given on the palæontological facies of the Silurian and Carboniferous formations, the fossils from the latter having been determined by Dr. G. W. Lee and the late W. H. Baily. The mines and minerals of the district, as well as the soils and agriculture, form further sections of this report. Its extremely low price should commend this excellent work to all interested in Irish geology.

7. A Review of Mining Operations in the State of South Australia during the half-year ended December 31, 1914. No. 21. 8vo; pp. 35. Adelaide, 1915.

This is mainly of statistical interest to mining experts. There are, however, certain particulars given of boring operations which have been carried out at the Poona and Mattapara Mines, Moonta, by Mr. A. W. Matthews, and also at Calcookra Mine near Franklin Harbour by Mr. C. F. Duffield, which illustrate the rock structures of those districts. Mr. R. Lockhart Jack (Assistant Government Geologist) refers to the discovery of Alunite deposits on Section 310 at Hundred of Napperley, of which assays and analyses by W. S. Chapman are given. The Government Geologist, Mr. L. K. Ward, contributes a note on the cobalt deposits.

8. The Geology of the Appleby District. By Dr. John Edward Marr, M.A., F.R.S. With special reference to the area visited during the long excursion of 1907 by the London Geologists' Association. (Reprinted from the Proceedings of the Geologists' Association by permission of the Council of the Association.) Notes on the Geology of the Vale of Eden, by Professor P. F. Kendall. Appendix on the Igneous Rocks, by Alfred Harker. 8vo; pp. 27, with geological

maps and views. Appleby, 1915 (but not dated). Price 1*s*.—This work forms a useful guide to the geological structure of this district, and should be much sought after by tourists interested in the structure of rocks, the Appleby region being one of the best centres for such studies in Great Britain. Dr. Marr's portion of the work is a re-issue of his *Geology of the Appleby District*, published some years since, which, according to a newspaper paragraph, is now "brought up to date".

9. Catalogue of the Books, Manuscripts, Maps, and Drawings in the British Museum (Natural History). Vol. V: SO–Z. 4to; pp. 1957–2403. London: Dulau & Co., 1915. Price £1 per volume.—We have already spoken (Geol. Mag., 1903, pp. 415–18; 1910, pp. 475–6) of the merits and value of this Catalogue, and have therefore only to call attention to the completion of the main work. Mr. B. B. Woodward has fortunately catalogued the whole series from A to Z, and thus the publication has an uniformity and completeness unusual in so large an undertaking. While congratulating Mr. Woodward and expressing our indebtedness to him for the relief he has afforded to all those who struggle through scientific literature, we hope we shall not be indiscreet in mentioning that a supplementary volume which will include many additions and rarities acquired while the Catalogue has been going through the press (1903–15) has been arranged for. The manuscript for this is already nearly finished and will include the large and valuable library of entomological books and serials handed over by Lord Walsingham to the Museum with his collection of microlepidoptera. And advantage will be taken for the inclusion of bibliographic matter of any importance affecting the main entries, emendations of dates, and other detail for which we look in vain in most catalogues of the kind.

MISCELLANEOUS.

The Royal Society of Canada, Ottawa.—Mr. J. B. Tyrrell, M.A., M.Inst.M.M., F.R.S. (Canada), F.G.S., Mining Engineer, of Toronto, was elected President of the Geological Section of the Royal Society of Canada at its annual meeting held in Ottawa on May 25–7.

Erratum.—In the August Number, p. 353, footnote [1] (third line), for "deposited by the Rhine Glacier", read "Rhone Glacier".

The following lines, indited by a friend after reading Matthew Arnold on Culture, have reached the Editor's box, and may serve to relieve the tedium of the season:—

Culture and Kultur.

While *Culture* in Britain induces
Swifter progress to Sweetness and Light,
His *Kultur* the German seduces
Towards Arrogance, Envy, and Spite.

T. V. H.